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(54) Title: NOVEL P-SELECTIN LIGAND PROTEIN (57) Abstract A novel P-selectin ligand glycoprotein is disclosed, characterized by the amino acid sequence set forth in SEQ ID NO:1 or by the amino acid sequence set forth in SEQ ID NO:3. DNA sequences encoding the P-selectin ligand protein are also disclosed, along with vectors, host cells, and methods of making the P-selectin ligand protein. Pharmaceutical compositions containing the P-selectin ligand protein and methods of treating inflammatory disease states characterized by P-selectin-mediated intercellular adhesion are also disclosed.		

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TITLE OF THE INVENTION

NOVEL P-SELECTIN LIGAND PROTEIN

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BACKGROUND OF THE INVENTION

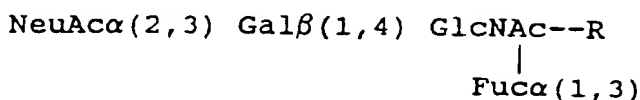
15 The present invention relates to the field of anti-inflammatory substances which act by inhibiting leukocyte adhesion to endothelial cells. More particularly, the present invention is directed to a novel ligand for the mammalian adhesion protein known as "P-selectin."

20 During inflammation leukocytes adhere to the vascular endothelium and enter subendothelial tissue, an interaction which is mediated by specific binding of the selectin or LEC-CAM class of proteins to ligands on target cells. Such selectin-mediated cellular adhesion also occurs in thrombotic disorders and parasitic diseases and may be implicated in metastatic spread of
25 tumor cells.

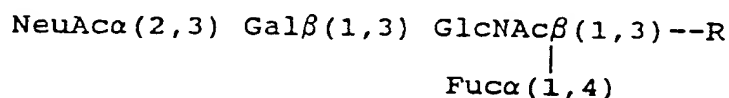
The selectin proteins are characterized by a N-terminal lectin-like domain, an epidermal growth factor-like domain, and regions of homology to complement binding proteins. Thus far three human selectin proteins have been identified, E-selectin
30 (formerly ELAM-1), L-selectin (formerly LAM-1) and P-selectin (formerly PADGEM or GMP-140). E-selectin is induced on endothelial cells several hours after activation by cytokines, mediating the calcium-dependent interaction between neutrophils and the endothelium. L-selectin is the lymphocyte homing
35 receptor, and P-selectin rapidly appears on the cell surface of platelets when they are activated, mediating calcium-dependent adhesion of neutrophils or monocytes to platelets. P-selectin is also found in the Weibel-Palade bodies of endothelial cells; upon its release from these vesicles P-selectin mediates early

binding of neutrophils to histamine-or thrombin-stimulated endothelium.

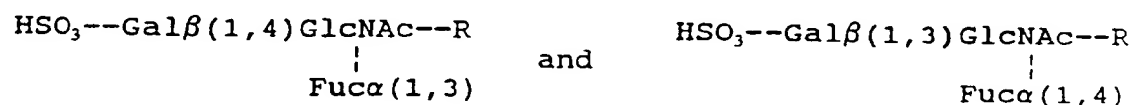
Selectins are believed to mediate adhesion through specific interactions with ligands present on the surface of target cells. Generally the ligands of selectins are comprised at least in part of a carbohydrate moiety. For example, E-selectin binds to carbohydrates having the terminal structure



and also to carbohydrates having the terminal structure



where R =the remainder of the carbohydrate chain. These carbohydrates are known blood group antigens and are commonly referred to as sialylated Lewis^x and sialylated Lewis^y, respectively. The presence of the sialylated Lewis^x antigen alone on the surface of an endothelial cell may be sufficient to promote binding to an E-selectin expressing cell. E-selectin also binds to carbohydrates having the terminal structures



As with E-selectin, each selectin appears to bind to a range of carbohydrates with varying affinities. The strength of the selectin mediated adhesive event (binding affinity) may also depend on the density of the carbohydrate and on the density of the selectin on the cell surface.

P-selectin binds to carbohydrates containing the non-sialylated form of the Lewis^x blood group antigen and with higher affinity to sialylated Lewis^x. P-selectin may also recognize sulfatides, which are heterogeneous 3-sulfated galactosyl ceramides, isolated from myeloid and tumor cells by lipid extraction. However, the binding of cells bearing P-selectin to cells bearing P-selectin ligands is abolished when the ligand-bearing cells are treated with proteases, indicating that the P-selectin ligand may be a glycoprotein.

Two putative glycoprotein ligands for P-selectin have recently been identified, one of which has been partially purified, (Moore et al., J. Cell Biol. 118, 445-456 (1992)). However, neither amino acid composition nor the amino acid sequence of these glycoproteins are disclosed.

SUMMARY OF THE INVENTION

In one embodiment, the present invention provides a composition comprising an isolated DNA sequence encoding a P-selectin ligand protein, said protein being characterized by the amino acid sequence set forth in SEQ ID NO:1 from amino acid 1 to amino acid 402. Also provided is a composition comprising an isolated DNA sequence encoding a soluble P-selectin ligand protein, said protein being characterized by the amino acid sequence set forth in SEQ ID NO:1 from amino acid 1 to amino acid 310. The invention further provides a composition comprising an isolated DNA sequence encoding a mature P-selectin ligand protein, said protein being characterized by the amino acid sequence set forth in SEQ ID NO:1 from amino acid 42 to amino acid 402. In another embodiment, the invention provides a composition comprising an isolated DNA sequence encoding a soluble mature P-selectin ligand protein, said protein being characterized by the amino acid sequence set forth in SEQ ID NO:1 from amino acid 42 to amino acid 310. In another embodiment, the invention provides a composition comprising an isolated DNA sequence encoding a P-selectin ligand protein, said protein being characterized by the amino acid sequence set forth in SEQ ID NO:3. The invention further provides a composition comprising

an expression vector comprising any one of the isolated DNA sequences of the invention, said DNA sequence being operably linked to an expression control sequence; a host cell transformed with the expression vector containing any one of the DNA sequences described above; and a process for producing the P-selectin ligand protein, which comprises:

- (a) culturing a host cell transformed with an expression vector containing any one of the DNA sequences of the invention in a suitable culture medium; and
- (b) purifying the P-selectin ligand protein from the culture medium.

In another embodiment, the invention provides a composition comprising a protein characterized by the amino acid sequence set forth in SEQ ID NO:1 from amino acid 21 to amino acid 402, said protein being substantially free from other mammalian proteins. The invention further comprises a soluble P-selectin ligand protein characterized by the amino acid sequence set forth in SEQ ID NO:1 from amino acid 21 to amino acid 310, said protein being substantially free from other mammalian proteins, and in another embodiment, the invention comprises a P-selectin ligand protein characterized by the amino acid sequence set forth in SEQ ID NO:1 from amino acid 1 to amino acid 402, said protein being substantially free from other mammalian proteins. The invention also provides a composition comprising a mature P-selectin ligand protein characterized by the amino acid sequence set forth in SEQ ID NO:1 from amino acid 42 to amino acid 402, said protein being substantially free from other mammalian proteins. Further provided is a composition comprising a soluble mature P-selectin ligand protein characterized by the amino acid sequence set forth in SEQ ID NO:1 from amino acid 42 to amino acid 310, said protein being substantially free from other mammalian proteins. In another embodiment the invention provides a composition comprising a protein characterized by the amino acid sequence set forth in SEQ ID NO:3.

In yet another embodiment, the invention provides a composition comprising an antibody specific for the P-selectin ligand protein.

In another embodiment, the invention provides a method of identifying an inhibitor of P-selectin-mediated intercellular adhesion which comprises

(a) combining a P-selectin protein with a P-selectin ligand protein characterized by an amino acid sequence selected from the group consisting of the amino acid sequence set forth in SEQ ID NO:1 from amino acid 1 to amino acid 402, the amino acid sequence set forth in SEQ ID NO:1 from amino acid 42 to amino acid 402, the amino acid sequence set forth in SEQ ID NO:1 from amino acid 42 to amino acid 310, and the amino acid sequence set forth in SEQ ID NO:3, said combination forming a first binding mixture;

(b) measuring the amount of binding between the P-selectin protein and the P-selectin ligand protein in the first binding mixture;

(c) combining a compound with the P-selectin protein and the P-selectin ligand protein to form a second binding mixture;

(d) measuring the amount of binding in the second binding mixture; and

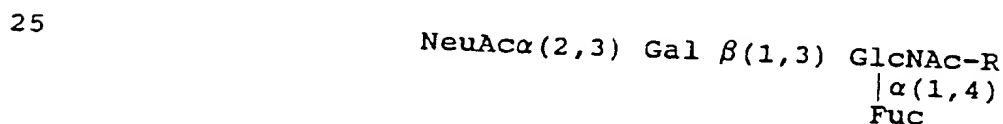
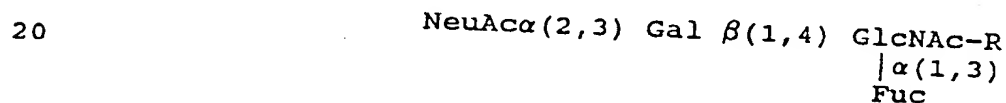
(e) comparing the amount of binding in the first binding mixture with the amount of binding in the second binding mixture; wherein the compound is capable of inhibiting P-selectin-mediated intercellular adhesion when a decrease in the amount of binding of the second binding mixture occurs.

DETAILED DESCRIPTION OF THE INVENTION

The present inventors have for the first time identified and isolated a novel DNA which encodes a protein which acts as a ligand for P-selectin on human endothelial cells and platelets. The complete amino acid sequence of the P-selectin ligand protein (i.e., the mature peptide plus the leader sequence) is characterized by the amino acid sequence set forth in SEQ ID NO:1 from amino acid 1 to amino acid 402. Hydrophobicity analysis and comparison with known cleavage patterns predict a signal sequence of 20 to 22 amino acids, i.e., amino acids 1 to 20 or amino acids 1 to 22 of SEQ ID NO:1. The P-selectin ligand protein contains

a PACE (paired basic amino acid converting enzyme) cleavage site (-Arg-Asp-Arg-Arg-) at amino acids 38-41 of SEQ ID NO:1. The mature P-selectin ligand protein of the present invention is characterized by the amino acid sequence set forth in SEQ ID NO:1 from amino acid 42 to amino acid 402. A soluble form of the P-selectin ligand protein is characterized by containing amino acids 21 to 310 of SEQ ID NO:1. Another soluble form of the mature P-selectin ligand protein is characterized by the amino acid sequence set forth in SEQ ID NO:1 from amino acid 42 to amino acid 310. The soluble form of the P-selectin ligand protein is further characterized by being soluble in aqueous solution at room temperature. Of course, the corresponding DNA sequences as set forth in SEQ ID NO:1 encoding these proteins are also included in the subject invention.

The P-selectin ligand of the invention is a glycoprotein which may contain one or more of the following terminal carbohydrates:



40 where R= the remainder of the carbohydrate chain, which is covalently attached either directly to the P-selectin ligand protein or to a lipid moiety which is covalently attached to the P-selectin ligand protein. The P-selectin ligand glycoprotein of the invention may additionally be sulfated or otherwise post-

translationally modified. As expressed in COS and CHO cells, full length P-selectin ligand protein (amino acids 1 to 402 of SEQ ID NO:1 or amino acids 42 to 402 of SEQ ID NO:1) is a homodimeric protein having an apparent molecular of 220 kD as shown by non-reducing SDS-polyacrylamide gel electrophoresis.

Three regions of the P-selectin ligand protein of SEQ ID NO:1 are: an extracellular domain (from about amino acid 21 to 310 of SEQ ID NO:1), a transmembrane domain (from about amino acid 311 to 332 of SEQ ID NO:1), and an intracellular, cytoplasmic domain (from about amino acid 333 to 402 of SEQ ID NO:1). The extracellular domain contains three consensus tripeptide sites (Asn-X-Ser/Thr) of potential N-linked glycosylation beginning at Asn residues 65, 111, and 292. The extracellular domain further contains three potential sites of tyrosine sulfation at residues 46, 48, and 51. The region comprised of residues 55-267 contains a high percentage of proline, serine, and threonine including a subdomain of fifteen decameric repeats of the ten amino acid consensus sequence Ala-Thr/Met-Glu-Ala-Gln-Thr-Thr-X-Pro/Leu-Ala/Thr, wherein X can be either Pro, Ala, Gln, Glu, or Arg. Regions such as these are characteristic of highly O-glycosylated proteins.

COS or CHO cells co-transfected with a gene encoding the P-selectin ligand protein and a gene encoding an (α 1,3/1,4) fucosyltransferase (hereinafter 3/4FT) are capable of binding to CHO cells expressing P-selectin on their surface, but are not capable of binding to CHO cells which do not express P-selectin on their surface. In order to bind to P-selectin, either in purified form or expressed on the surface of CHO cells, the gene encoding the P-selectin ligand protein must be co-transfected with the gene encoding a 3/4FT, since transfection of either gene in the absence of the other either abolishes or substantially reduces the P-selectin binding activity. The binding of the P-selectin ligand protein of the invention to P-selectin can be inhibited by EDTA or by a neutralizing monoclonal antibody specific for P-selectin. The binding of the P-selectin ligand protein of the invention to P-selectin is not inhibited by a non-neutralizing monoclonal antibody specific for P-selectin or by

an isotype control. These results characterize the binding specificity of the P-selectin ligand protein of the invention.

For the purposes of the present invention, a protein is defined as having "P-selectin ligand protein activity", i.e.,
5 variably referred to herein as a "P-selectin ligand protein", or as a "P-selectin ligand glycoprotein" or simply as a "P-selectin ligand", when it binds in a calcium-dependent manner to P-selectin which is present on the surface of cells as in the CHO-P-selectin binding assay of Example 4, or to P-selectin which is
10 affixed to another surface, for example, as the chimeric P-selectin-IgGyl protein of Example 4 is affixed to Petri dishes.

The glycosylation state of the P-selectin ligand protein of the invention was studied using a chimeric, soluble form of the P-selectin ligand protein, described in detail in Example 5(C)
15 and designated sPSL.T7. The sPSL.T7 protein produced from COS cells co-transfected with 3/4FT is extensively modified by posttranslational glycosylation, as described in detail in Example 6(C). Thus, it is believed that both N- and O-linked oligosaccharide chains, at least some of which are sialylated,
20 are present on the P-selectin ligand protein of the invention.

The P-selectin ligand protein of the invention may also bind to E-selectin. Conditioned medium from COS cells which have been co-transfected with the DNA encoding sPSL.T7 and with the DNA encoding 3/4FT, when coated on wells of plastic microtiter
25 plates, causes CHO cells which express E-selectin to bind to the plates; however CHO cells which do not express E-selectin do not bind to such plates. The binding of CHO cells which express E-selectin to microtiter plates coated with conditioned medium from COS cells which have been co-transfected with the DNA encoding
30 sPSL.T7 and with the DNA encoding 3/4FT is abolished in the presence of EDTA or of a neutralizing antibody specific for E-selectin. Conditioned medium from COS cells transfected only with the sPSL.T7 DNA does not cause binding of CHO cells which express E-selectin when coated on wells of microtiter plates.
35 For these reasons, the P-selectin ligand protein of the invention is believed to be useful as an inhibitor of E-selectin-mediated

intercellular adhesion in addition to P-selectin-mediated intercellular adhesion.

Fragments of the P-selectin ligand protein which are capable of interacting with P-selectin or which are capable of inhibiting P-selectin-mediated intercellular adhesion are also encompassed by the present invention. Such fragments comprise amino acids 21 to 54 of SEQ ID NO:1, a region of the P-selectin ligand protein having a low frequency of serine and threonine residues; amino acids 55 to 127 of SEQ ID NO:1, having a high frequency of proline, serine, and threonine in addition to two consensus sequences for asparagine-linked glycosylation (Asn-X-Ser/Thr); another larger fragment, amino acids 128 to 267 of SEQ ID NO:1, having both a high frequency of proline, serine, and threonine and containing fifteen repeats of the following ten amino acid consensus sequence: Ala-(Thr/Met)-Glu-Ala-Gln-Thr-Thr-(Pro/Arg/Gln/Ala/Glu)-(Leu/Pro)-(Ala/Thr) (smaller fragments within this large fragment may also retain the capacity to interact with P-selectin or act as inhibitors of P-selectin-mediated intercellular adhesion); the region containing a consensus sequence for asparagine-linked glycosylation and comprising amino acids 268 to 308 of SEQ ID NO:1; the hydrophobic region of the protein represented by amino acids 309 to 333 of SEQ ID NO:1; and the amphiphilic region of the P-selectin ligand protein from amino acids 334 to 402. Additional fragments may comprise amino acid 43 to amino acid 56 of SEQ ID NO:1, with one or more sulfated tyrosines at amino acid 46, amino acid 48, and/or amino acid 51. Fragments of the P-selectin ligand protein may be in linear form or they may be cyclized using known methods, for example, as described in H.U. Saragovi, et al., Bio/Technology 10, 773-778 (1992) and in R.S. McDowell, et al., J. Amer. Chem. Soc. 114, 9245-9253 (1992), both of which are incorporated herein by reference. For the purposes of the present invention, all references to "P-selectin ligand protein" herein include fragments capable of binding to P-selectin.

Such fragments may be fused to carrier molecules such as immunoglobulins, to increase the valency of P-selectin ligand binding sites. For example, soluble forms of the P-selectin

ligand protein such as the fragment from amino acid 42 to amino acid 295 of SEQ ID NO:1 may be fused through "linker" sequences to the Fc portion of an immunoglobulin. For a bivalent form of the P-selectin ligand protein, such a fusion could be to the Fc portion of an IgG molecule as in Example 5(D) and in SEQ ID NO:6. Other immunoglobulin isotypes may also be used to generate such fusions. For example, a P-selectin ligand protein - IgM fusion would generate a decavalent form of the P-selectin ligand protein of the invention.

As detailed in the Examples below, the P-selectin ligand protein of the invention was initially obtained using an expression cloning approach (Clark et al. U.S. 4,675,285). A cDNA library was constructed from the human promyelocytic cell line HL60 (S.J. Collins, et al., Nature 270, 347-349 (1977), ATCC No. CCL 240). This library was cotransfected into COS cells with a DNA encoding a 3/4FT, and the cotransfectants were screened for binding to a chimeric molecule consisting of the extracellular portion of P-selectin and the Fc portion of a human IgG γ 1 monoclonal antibody. Cotransfectants which bound to the chimeric P-selectin were enriched for cDNAs encoding the P-selectin ligand protein. This screening process was repeated several times to enrich the plasmid population further for cDNAs encoding the P-selectin ligand protein. In a second cloning stage, the enriched plasmid population was again cotransfected into COS cells with the 3/4FT gene and screened for binding to a fluorescently labeled CHO cell line which expressed P-selectin on the cell surface. A single cDNA clone was obtained from this approach and was designated PMT21:PL85. The PMT21:PL85 plasmid was deposited with the American Type Culture Collection on October 16, 1992 and given the accession number ATCC 69096.

One novel DNA of the present invention is set forth in SEQ ID NO:1. The DNA of the present invention may encode a variety of forms of the P-selectin ligand protein. For example, in one embodiment, the DNA sequence of the invention encodes the entire P-selectin ligand protein having the amino acid sequence set forth in SEQ ID NO:1 from amino acid 1 to amino acid 402. In another embodiment, the DNA sequence of the invention encodes a

form of the P-selectin ligand protein which lacks the signal sequence and which is characterized by the amino acid sequence set forth in SEQ ID NO:1 from amino acid 21 to amino acid 402. In yet another embodiment, the DNA sequence of the invention encodes the mature P-selectin ligand protein characterized by the amino acid sequence set forth in SEQ ID NO:1 from amino acid 42 to amino acid 402. Another embodiment of the DNA sequence of the invention encodes a soluble form of the P-selectin ligand protein characterized by the amino acid sequence set forth in SEQ ID NO:1 from amino acid 1 to amino acid 310. The DNA of the invention is also embodied in a DNA sequence encoding a soluble form of the mature P-selectin ligand protein, said protein being characterized by the amino acid sequence set forth in SEQ ID NO:1 from amino acid 42 to amino acid 310. The DNA of the invention is further embodied in a DNA sequence encoding a soluble form of the P-selectin ligand protein which lacks the signal sequence, said protein being characterized by the amino acid sequence set forth in SEQ ID NO:1 from amino acid 21 to amino acid 310. The DNA of the present invention is free from association with other human DNAs and is thus characterized as an isolated DNA. As detailed above, DNAs which encode P-selectin ligand fragments which interact with P-selectin are also included in the present invention.

The expression of P-selectin ligand protein mRNA transcripts has been observed in a variety of human cell lines (HL-60, THP-1, U937) and in human monocytes and polymorphonuclear leukocytes by Northern analysis using a P-selectin ligand protein cDNA probe. In all of these cell lines, a major transcript of 2.5 kb was observed. A minor species of approximately 4 kb was observed in the HL60 and U937 cell lines and in polymorphonuclear leukocytes. In contrast, no P-selectin ligand mRNA expression was detected in the human hepatoblastoma cell line HepG2.

The P-selectin ligand protein of the invention is encoded by a single copy gene and is not part of a multi-gene family, as determined by Southern blot analysis. The genomic form of the P-selectin ligand protein of the invention contains a large intron of approximately 9 kb located at nucleotide 54 in the 5'

untranslated region. In polymorphonuclear leukocytes and monocytes, the P-selectin ligand protein of the invention is encoded by the DNA sequence set forth in SEQ ID NO:3. In this embodiment, the P-selectin ligand protein contains sixteen repeat regions. The isolated DNA of the invention is correspondingly also embodied in the DNA sequence set forth in SEQ ID NO:3 and is contained on plasmid pPL85R16 which was deposited with the American Type Culture Collection on October 22, 1993 and given the Accession Number ATCC _____.

The invention also encompasses allelic variations of the isolated DNA as set forth in SEQ ID NO:1 or of the isolated DNA as set forth in SEQ ID NO:3, that is, naturally-occurring alternative forms of the isolated DNA of SEQ ID NO: 1 or SEQ ID NO:3 which also encode proteins having P-selectin ligand activity. Also included in the invention are isolated DNAs which hybridize to the DNA set forth in SEQ ID NO:1 or to the DNA set forth in SEQ ID NO:3 under stringent (e.g. 4xSSC at 65°C or 50% formamide and 4xSSC at 42°C), or relaxed (4xSSC at 50°C or 30-40% formamide at 42°C) conditions, and which have P-selectin ligand protein activity. Isolated DNA sequences which encode the P-selectin ligand protein but which differ from the DNA set forth in SEQ ID NO:1 or from the DNA set forth in SEQ ID NO:3 by virtue of the degeneracy of the genetic code and which have P-selectin ligand protein activity are also encompassed by the present invention. Variations in the DNA as set forth in SEQ ID NO:1 or in the DNA as set forth in SEQ ID NO:3 which are caused by point mutations or by induced modifications which enhance the P-selectin ligand activity, half-life or production level are also included in the invention. For the purposes of the present invention all references herein to the "DNA of SEQ ID NO:1" include, in addition to the specific DNA sequence set forth in SEQ ID NO:1, DNA sequences encoding the mature P-selectin ligand protein of SEQ ID NO:1; DNA sequences encoding fragments of the P-selectin ligand protein of SEQ ID NO:1 which are capable of binding to P-selectin; DNA sequences encoding soluble forms of the P-selectin ligand protein of SEQ ID NO:1; allelic variations of the DNA sequence of SEQ ID NO:1; DNAs which hybridize to the

DNA sequence of SEQ ID NO:1 and which encode proteins having P-selectin ligand protein activity; DNAs which differ from the DNA of SEQ ID NO:1 by virtue of degeneracy of the genetic code; and the variations of the DNA sequence of SEQ ID NO:1 set forth
5 above. Similarly, all references to the "DNA of SEQ ID NO:3" include in addition to the specific DNA sequence set forth in SEQ ID NO:3, DNA sequences encoding the mature P-selectin ligand protein of SEQ ID NO:3; DNA sequences encoding fragments of the P-selectin ligand protein of SEQ ID NO:3 which are capable of
10 binding to P-selectin; DNA sequences encoding soluble forms of the P-selectin ligand protein of SEQ ID NO:3; allelic variations of the DNA sequence of SEQ ID NO:3; DNAs which hybridize to the DNA sequence of SEQ ID NO:3 and which encode proteins having P-selectin ligand protein activity; DNAs which differ from the DNA
15 of SEQ ID NO:3 by virtue of degeneracy of the genetic code; and the variations of the DNA sequence of SEQ ID NO:3 set forth above.

A DNA encoding a soluble form of the P-selectin ligand protein may be prepared by expression of a modified DNA in which
20 the regions encoding the transmembrane and cytoplasmic domains of the P-selectin ligand protein are deleted and/or a stop codon is introduced 3' to the codon for the amino acid at the carboxy terminus of the extracellular domain. For example, hydrophobicity analysis predicts that the P-selectin ligand
25 protein set forth in SEQ ID NO:1 has a transmembrane domain comprised of amino acids 311 to 332 of SEQ ID NO:1 and a cytoplasmic domain comprised of amino acids 333 to 402 of SEQ ID NO:1. A modified DNA as described above may be made by standard molecular biology techniques, including site-directed mutagenesis
30 methods which are known in the art or by the polymerase chain reaction using appropriate oligonucleotide primers. Methods for producing several DNAs encoding various soluble P-selectin ligand proteins are set forth in Example 5.

The isolated DNA of the invention may be operably linked to
35 an expression control sequence such as the pMT2 or pED expression vectors disclosed in Kaufman et al., Nucleic Acids Res. 19, 4485-4490 (1991), in order to produce the P-selectin ligand

recombinantly. Many suitable expression control sequences are known in the art. General methods of expressing recombinant proteins are also known and are exemplified in R. Kaufman, Methods in Enzymology 185, 537-566 (1990). As defined herein

5 "operably linked" means enzymatically or chemically ligated to form a covalent bond between the isolated DNA of the invention and the expression control sequence, in such a way that the P-selectin ligand protein is expressed by a host cell which has been transformed (transfected) with the ligated DNA/expression
10 control sequence.

Several endoproteolytic enzymes are known which cleave precursor peptides at the carboxyl side of paired amino acid sequences (e.g., -Lys-Arg- and -Arg-Arg-) to yield mature proteins. Such enzymes are generally known as paired basic amino
15 acid converting enzymes or PACE, and their use in recombinant production of mature peptides is extensively disclosed in WO 92/09698 and U.S. Application Serial No. 07/885,972, both of which are incorporated herein by reference. The PACE family of enzymes are known to increase the efficiency of proteolytic
20 processing of precursor polypeptides in recombinant host cells. As mentioned above, the P-selectin ligand protein of the invention contains such a PACE cleavage site.

The soluble mature P-selectin ligand protein of the present invention may be made by a host cell which contains a DNA
25 sequence encoding any soluble P-selectin ligand protein as described herein and a DNA sequence encoding PACE as described in WO 92/09698 and U.S. Application Serial No. 07/885,972, incorporated herein by reference, or using the DNA sequence of SEQ ID NO:5. Such a host cell may contain the DNAs as the result
30 of co-transformation or sequential transformation of separate expression vectors containing the soluble P-selectin ligand protein DNA and the PACE DNA, respectively. A third DNA which encodes a 3/4FT may also be co-transformed with the DNAs encoding the P-selectin ligand protein and PACE. Alternatively, the host
35 cell may contain the DNAs as the result of transformation of a single expression vector containing both soluble P-selectin ligand protein DNA and PACE DNA. Construction of such expression

vectors is within the level of ordinary skill in molecular biology. Methods for co-transformation and transformation are also known.

Many DNA sequences encoding PACE are known. For example, a DNA encoding one form of PACE, known as furin, is disclosed in A.M.W. van den Ouweland et al., Nucl. Acids Res. 18, 664 (1990), incorporated herein by reference. A cDNA encoding a soluble form of PACE, known as PACESOL, is set forth in SEQ ID NO:5. DNAs encoding other forms of PACE also exist, and any such PACE-encoding DNA may be used to produce the soluble mature P-selectin ligand protein of the invention, so long as the PACE is capable of cleaving the P-selectin ligand protein at amino acids 38-41. Preferably, a DNA encoding a soluble form of PACE is used to produce the soluble mature P-selectin ligand protein of the present invention.

The DNAs encoding a soluble form of the P-selectin ligand protein and PACE, separately or together, may be operably linked to an expression control sequence such as those contained in the pMT2 or pED expression vectors discussed above, in order to produce the PACE-cleaved soluble P-selectin ligand recombinantly. Additional suitable expression control sequences are known in the art. Examples 3(C) and 3(D) below set forth methods for producing the soluble mature P-selectin ligand protein of the invention.

A number of types of cells may act as suitable host cells for expression of the P-selectin ligand protein. Suitable host cells are capable of attaching carbohydrate side chains characteristic of functional P-selectin ligand protein. Such capability may arise by virtue of the presence of a suitable glycosylating enzyme within the host cell, whether naturally occurring, induced by chemical mutagenesis, or through transfection of the host cell with a suitable expression plasmid containing a DNA sequence encoding the glycosylating enzyme. Host cells include, for example, monkey COS cells, Chinese Hamster Ovary (CHO) cells, human kidney 293 cells, human epidermal A431 cells, human Colo205 cells, 3T3 cells, CV-1 cells, other transformed primate cell lines, normal diploid cells, cell

strains derived from in vitro culture of primary tissue, primary explants, HeLa cells, mouse L cells, BHK, HL-60, U937, or HaK cells.

5 The P-selectin ligand protein may also be produced by operably linking the isolated DNA of the invention and one or more DNAs encoding suitable glycosylating enzymes to suitable control sequences in one or more insect expression vectors, and employing an insect expression system. Materials and methods for baculovirus/insect cell expression systems are commercially
10 available in kit form from, e.g., Invitrogen, San Diego, California, U.S.A. (the MaxBac® kit), and such methods are well known in the art, as described in Summers and Smith, Texas Agricultural Experiment Station Bulletin No. 1555 (1987), incorporated herein by reference. Soluble forms of the P-selectin ligand protein may also be produced in insect cells
15 using appropriate isolated DNAs as described above. A DNA encoding a form of PACE may further be co-expressed in an insect host cell to produce a PACE-cleaved form of the P-selectin ligand protein.

20 Alternatively, it may be possible to produce the P-selectin ligand protein in lower eukaryotes such as yeast or in prokaryotes such as bacteria. Potentially suitable yeast strains include *Saccharomyces cerevisiae*, *Schizosaccharomyces pombe*, *Kluyveromyces* strains, *Candida*, or any yeast strain capable of
25 expressing heterologous proteins. Potentially suitable bacterial strains include *Escherichia coli*, *Bacillus subtilis*, *Salmonella typhimurium*, or any bacterial strain capable of expressing heterologous proteins. If the P-selectin ligand protein is made in yeast or bacteria, it is necessary to attach the appropriate
30 carbohydrates to the appropriate sites on the protein moiety covalently, in order to obtain the glycosylated P-selectin ligand protein. Such covalent attachments may be accomplished using known chemical or enzymatic methods.

35 The P-selectin ligand protein of the invention may also be expressed as a product of transgenic animals, e.g., as a component of the milk of transgenic cows, goats, pigs, or sheep

which are characterized by somatic or germ cells containing a DNA sequence encoding the P-selectin ligand protein.

5 The P-selectin ligand protein of the invention may be prepared by culturing transformed host cells under culture conditions necessary to express a P-selectin binding glycoprotein. The resulting expressed glycoprotein may then be purified from culture medium or cell extracts. Soluble forms of the P-selectin ligand protein of the invention can be purified by affinity chromatography over Lentil lectin-Sepharose® and subsequent elution with 0.5M α -methyl-mannoside. The eluted soluble P-selectin ligand protein can then be further purified and concentrated by a 0-70% ammonium sulfate precipitation step. The protein is then recovered, resuspended, and further purified by size exclusion chromatography over a TSK G4000SW_{XL}.
10 Alternatively, full length forms of the P-selectin ligand protein of the invention can be purified by preparing a total membrane fraction from the expressing cell and extracting the membranes with a non-ionic detergent such as Triton X-100. The detergent extract can then be passed over an affinity column comprised of immobilized P-selectin, and the P-selectin ligand protein can be eluted from the column with 10mM EDTA in a buffer containing 0.1% detergent. The material eluted from the affinity column can then be dialyzed to remove EDTA and further purified over a Lentil lectin-Sepharose® affinity column, again eluting with 0.5M α -methyl-mannoside.
25

Alternatively, the P-selectin ligand protein of the invention is concentrated using a commercially available protein concentration filter, for example, an Amicon or Millipore Pellicon ultrafiltration unit. Following the concentration step, the concentrate can be applied to a purification matrix such as a gel filtration medium. Alternatively, an anion exchange resin can be employed, for example, a matrix or substrate having pendant diethylaminoethyl (DEAE) groups. The matrices can be acrylamide, agarose, dextran, cellulose or other types commonly employed in protein purification. Alternatively, a cation exchange step can be employed. Suitable cation exchangers include various insoluble matrices comprising sulfopropyl or
30
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carboxymethyl groups. Sulfopropyl groups are preferred (e.g., S-Sepharose® columns). The purification of the P-selectin ligand protein from culture supernatant may also include one or more column steps over such affinity resins as concanavalin A-agarose, heparin-toyopearl® or Cibacrom blue 3GA Sepharose®; or by hydrophobic interaction chromatography using such resins as phenyl ether, butyl ether, or propyl ether; or by immunoaffinity chromatography.

Finally, one or more reverse-phase high performance liquid chromatography (RP-HPLC) steps employing hydrophobic RP-HPLC media, e.g., silica gel having pendant methyl or other aliphatic groups, can be employed to further purify the P-selectin ligand protein. Some or all of the foregoing purification steps, in various combinations, can also be employed to provide a substantially homogeneous isolated recombinant protein. The P-selectin ligand protein thus purified is substantially free of other mammalian proteins and is defined in accordance with the present invention as "isolated P-selectin ligand protein".

The isolated P-selectin ligand protein may be useful in treating conditions characterized by P-selectin mediated intercellular adhesion. Such conditions include, without limitation, myocardial infarction, bacterial or viral infection, metastatic conditions, inflammatory disorders such as arthritis, acute respiratory distress syndrome, asthma, emphysema, delayed type hypersensitivity reaction, systemic lupus erythematosus, thermal injury such as burns or frostbite, autoimmune thyroiditis, experimental allergic encephalomyelitis, multiple sclerosis, multiple organ injury syndrome secondary to trauma, diabetes, Reynaud's syndrome, neutrophilic dermatosis (Sweet's syndrome), inflammatory bowel disease, Grave's disease, glomerulonephritis, gingivitis, periodontitis, hemolytic uremic syndrome, ulcerative colitis, Crohn's disease, necrotizing enterocolitis, granulocyte transfusion associated syndrome, cytokine-induced toxicity, and the like. The isolated P-selectin ligand protein may also be useful in organ transplantation, both to prepare organs for transplantation and to quell organ transplant rejection. The isolated P-selectin ligand protein may

be used to treat hemodialysis and leukophoresis patients. Additionally, the isolated P-selectin ligand protein may be used as an antimetastatic agent. The isolated P-selectin ligand protein may be used itself as an inhibitor of P-selectin-mediated intercellular adhesion or to design inhibitors of P-selectin-mediated intercellular adhesion. The present invention encompasses both pharmaceutical compositions containing isolated P-selectin ligand protein and therapeutic methods of treatment or use which employ the isolated P-selectin ligand protein.

The isolated P-selectin ligand protein, purified from cells or recombinantly produced, may be used as a pharmaceutical composition when combined with a pharmaceutically acceptable carrier. Such a composition may contain, in addition to the P-selectin ligand protein and carrier, diluents, fillers, salts, buffers, stabilizers, solubilizers, and other materials well known in the art. The term "pharmaceutically acceptable" means a non-toxic material that does not interfere with the effectiveness of the biological activity of the active ingredient(s). The characteristics of the carrier will depend on the route of administration. The pharmaceutical composition of the invention may also contain cytokines, lymphokines, or other hematopoietic factors such as M-CSF, GM-CSF, IL-1, IL-2, IL-3, IL-4, IL-5, IL-6, IL-7, IL-8, IL-9, IL-10, IL-11, IL-12, G-CSF, Meg-CSF, stem cell factor, and erythropoietin. The pharmaceutical composition may contain thrombolytic or anti-thrombotic factors such as plasminogen activator and Factor VIII. The pharmaceutical composition may further contain other anti-inflammatory agents. Such additional factors and/or agents may be included in the pharmaceutical composition to produce a synergistic effect with the isolated P-selectin ligand protein, or to minimize side effects caused by the isolated P-selectin ligand protein. Conversely, the isolated P-selectin ligand protein may be included in formulations of the particular cytokine, lymphokine, other hematopoietic factor, thrombolytic or anti-thrombotic factor, or anti-inflammatory agent to minimize side effects of the cytokine, lymphokine, other hematopoietic

factor, thrombolytic or anti-thrombotic factor, or anti-inflammatory agent.

5 The pharmaceutical composition of the invention may be in the form of a liposome in which the isolated P-selectin ligand protein is combined, in addition to other pharmaceutically acceptable carriers, with amphipathic agents such as lipids which exist in aggregated form as micelles, insoluble monolayers, liquid crystals, or lamellar layers which in aqueous solution. Suitable lipids for liposomal formulation include, without
10 limitation, monoglycerides, diglycerides, sulfatides, lysolecithin, phospholipids, saponin, bile acids, and the like. Preparation of such liposomal formulations is within the level of skill in the art, as disclosed, for example, in U.S. Patent No. 4,235,871; U.S. Patent No. 4,501,728; U.S. Patent No.
15 4,837,028; and U.S. Patent No. 4,737,323, all of which are incorporated herein by reference.

As used herein, the term "therapeutically effective amount" means the total amount of each active component of the pharmaceutical composition or method that is sufficient to show
20 a meaningful patient benefit, i.e., healing of chronic conditions characterized by P-selectin-mediated cellular adhesion or increase in rate of healing of such conditions. When applied to an individual active ingredient, administered alone, the term refers to that ingredient alone. When applied to a combination,
25 the term refers to combined amounts of the active ingredients that result in the therapeutic effect, whether administered in combination, serially or simultaneously.

In practicing the method of treatment or use of the present invention, a therapeutically effective amount of isolated P-selectin ligand protein is administered to a mammal having a P-selectin-mediated disease state. The isolated P-selectin ligand protein may be administered in accordance with the method of the
30 invention either alone or in combination with other therapies such as treatments employing cytokines, lymphokines or other hematopoietic factors. When co-administered with one or more
35 cytokines, lymphokines or other hematopoietic factors, the isolated P-selectin ligand protein may be administered either

simultaneously with the cytokine(s), lymphokine(s), other hematopoietic factor(s), thrombolytic or anti-thrombotic factors, or sequentially. If administered sequentially, the attending physician will decide on the appropriate sequence of administering the isolated P-selectin ligand protein in combination with cytokine(s), lymphokine(s), other hematopoietic factor(s), thrombolytic or anti-thrombotic factors.

Administration of the isolated P-selectin ligand protein used in the pharmaceutical composition or to practice the method of the present invention can be carried out in a variety of conventional ways, such as oral ingestion, inhalation, or cutaneous, subcutaneous, or intravenous injection. Intravenous administration to the patient is preferred.

When a therapeutically effective amount of isolated P-selectin ligand protein is administered orally, the isolated P-selectin ligand protein will be in the form of a tablet, capsule, powder, solution or elixir. When administered in tablet form, the pharmaceutical composition of the invention may additionally contain a solid carrier such as a gelatin or an adjuvant. The tablet, capsule, and powder contain from about 5 to 95% isolated P-selectin ligand protein, and preferably from about 25 to 90% isolated P-selectin ligand protein. When administered in liquid form, a liquid carrier such as water, petroleum, oils of animal or plant origin such as peanut oil, mineral oil, soybean oil, or sesame oil, or synthetic oils may be added. The liquid form of the pharmaceutical composition may further contain physiological saline solution, dextrose or other saccharide solution, or glycols such as ethylene glycol, propylene glycol or polyethylene glycol. When administered in liquid form, the pharmaceutical composition contains from about 0.5 to 90% by weight of the isolated P-selectin ligand protein and preferably from about 1 to 50% isolated P-selectin ligand protein.

When a therapeutically effective amount of isolated P-selectin ligand protein is administered by intravenous, cutaneous or subcutaneous injection, the isolated P-selectin ligand protein will be in the form of a pyrogen-free, parenterally acceptable aqueous solution. The preparation of such parenterally

acceptable protein solutions, having due regard to pH, isotonicity, stability, and the like, is within the skill in the art. A preferred pharmaceutical composition for intravenous, cutaneous, or subcutaneous injection should contain, in addition to the isolated P-selectin ligand protein an isotonic vehicle such as Sodium Chloride Injection, Ringer's Injection, Dextrose Injection, Dextrose and Sodium Chloride Injection, Lactated Ringer's Injection, or other vehicle as known in the art. The pharmaceutical composition of the present invention may also contain stabilizers, preservatives, buffers, antioxidants, or other additive known to those of skill in the art.

The amount of isolated P-selectin ligand protein in the pharmaceutical composition of the present invention will depend upon the nature and severity of the condition being treated, and on the nature of prior treatments which the patient has undergone. Ultimately, the attending physician will decide the amount of isolated P-selectin ligand protein with which to treat each individual patient. Initially, the attending physician will administer low doses of the isolated P-selectin ligand protein and observe the patient's response. Larger doses of isolated P-selectin ligand protein may be administered until the optimal therapeutic effect is obtained for the patient, and at that point the dosage is not increased further. It is contemplated that the various pharmaceutical compositions used to practice the method of the present invention should contain about 0.1 μ g to about 100 mg of isolated P-selectin ligand protein per kg body weight.

The duration of intravenous therapy using the pharmaceutical composition of the present invention will vary, depending on the severity of the disease being treated and the condition and potential idiosyncratic response of each individual patient. It is contemplated that the duration of each application of the isolated P-selectin ligand protein will be in the range of 12 to 24 hours of continuous intravenous administration. Ultimately the attending physician will decide on the appropriate duration of intravenous therapy using the pharmaceutical composition of the present invention.

The isolated P-selectin ligand protein of the invention may also be used to immunize animals to obtain polyclonal and monoclonal antibodies which specifically react with the p-selectin ligand protein and which may inhibit P-selectin-mediated cellular adhesion. Such antibodies may be obtained using the entire P-selectin ligand protein as an immunogen, or by using fragments of the P-selectin ligand protein such as the soluble mature P-selectin ligand protein. Smaller fragments of the P-selectin ligand protein may also be used to immunize animals, such as the fragments set forth below: amino acid 42 to amino acid 56 of SEQ ID NO:1 and amino acid 127 to amino acid 138 of SEQ ID NO:1. An additional peptide immunogen comprises amino acid 238 to amino acid 248 of SEQ ID NO:1, with an alanine residue added to the amino terminus of the peptide. Another peptide immunogen comprises amino acid 43 to amino acid 56 of SEQ ID NO:1 having a sulfated tyrosine in any or all of positions 46, 48 or 51. The peptide immunogens additionally may contain a cysteine residue at the carboxyl terminus, and are conjugated to a hapten such as keyhole limpet hemocyanin (KLH). Additional peptide immunogens may be generated by replacing tyrosine residues with sulfated tyrosine residues. Methods for synthesizing such peptides are known in the art, for example, as in R.P. Merrifield, J.Amer.Chem.Soc. 85, 2149-2154 (1963); J.L. Krstenansky, et al., FEBS Lett. 211, 10 (1987).

Monoclonal antibodies binding to the P-selectin ligand glycoprotein or to complex carbohydrate moieties characteristic of the P-selectin ligand glycoprotein may be useful diagnostic agents for the immunodetection of inflammatory diseases and some forms of cancer. Some cancerous cells, such as small cell lung carcinomas, may express detectable levels of the P-selectin ligand protein. This abnormal expression of the P-selectin ligand protein by cancer cells may play a role in the metastasis of these cells.

Neutralizing monoclonal antibodies binding to the P-selectin ligand glycoprotein or to complex carbohydrates characteristic of the P-selectin ligand glycoprotein may also be useful therapeutics for both inflammatory diseases and also in the

5 treatment of some forms of cancer where abnormal expression of
the P-selectin ligand protein is involved. These neutralizing
monoclonal antibodies are capable of blocking the selectin
mediated intercellular adherence function of the P-selectin
10 ligand protein. By blocking the binding of the P-selectin ligand
protein, the adherence of leukocytes to sites of inappropriate
inflammation is either abolished or markedly reduced. In the
case of cancerous cells or leukemic cells, neutralizing
monoclonal antibodies against the P-selectin ligand protein may
15 be useful in detecting and preventing the metastatic spread of
the cancerous cells which may be mediated by the P-selectin
ligand protein. In addition, the monoclonal antibodies bound to
these cells may target the cancerous cells for antibody-dependent
cell mediated cytotoxicity (ADCC), thus helping to eliminate the
20 cancerous cells. Human antibodies which react with the P-
selectin ligand protein may be produced in transgenic animals
which contain human immunoglobulin encoding genes in their germ
lines. Example 7 below sets forth production of a rabbit
polyclonal antibody specific for P-selectin ligand protein
fragments.

The P-selectin ligand protein of the invention may also be
used to screen for agents which are capable of binding to the P-
selectin ligand protein and thus may act as inhibitors of P-
selectin mediated intercellular adhesion. Binding assays using
25 a desired binding protein, immobilized or not, are well known in
the art and may be used for this purpose using the P-selectin
ligand protein of the invention. Appropriate screening assays
may be cell-based, as in Example 3 below. Alternatively,
purified protein based screening assays may be used to identify
30 such agents. For example, P-selectin ligand protein may be
immobilized in purified form on a carrier and binding to purified
P-selectin may be measured in the presence and in the absence of
potential inhibiting agents. A suitable binding assay may
alternatively employ purified P-selectin immobilized on a
35 carrier, with a soluble form of the P-selectin ligand protein of
the invention.

Any P-selectin ligand protein may be used in the screening assays described above. For example, the full-length P-selectin ligand protein set forth in SEQ ID NO:1 from amino acid 1 to amino acid 402 may be used to screen for inhibitors; or the
5 mature P-selectin ligand protein set forth in SEQ ID NO:1 from amino acid 42 to amino acid 402 may be used to screen for inhibitors, or the soluble mature P-selectin ligand protein set forth in SEQ ID NO:1 from amino acid 42 to amino acid 310 may be used to screen for inhibitors. Alternatively, the P-selectin
10 ligand protein of SEQ ID NO:3 from amino acid 1 to amino acid 412, or a mature form of the P-selectin ligand protein as set forth in SEQ ID NO:3 from amino acid 42 to amino acid 412, or a soluble mature form of the P-selectin ligand protein set forth in SEQ ID NO:3 from amino acid 42 to amino acid 320 may be used
15 to screen for inhibitors of intercellular adhesion in accordance with the present invention.

In such a screening assay, a first binding mixture is formed by combining P-selectin and the P-selectin ligand protein, and the amount of binding in the first binding mixture (B_0) is
20 measured. A second binding mixture is also formed by combining P-selectin, the P-selectin ligand protein, and the compound or agent to be screened, and the amount of binding in the second binding mixture (B) is measured. The amounts of binding in the first and second binding mixtures are compared, for example, by
25 performing a B/B_0 calculation. A compound or agent is considered to be capable of inhibiting P-selectin mediated intercellular adhesion if a decrease in binding in the second binding mixture as compared to the first binding mixture is observed. The formulation and optimization of binding mixtures is within the
30 level of skill in the art, such binding mixtures may also contain buffers and salts necessary to enhance or to optimize binding, and additional control assays may be included in the screening assay of the invention.

Compounds found to reduce by at least about 10%, preferably
35 greater than about 50% or more of the binding activity of P-selectin ligand protein to P-selectin may thus be identified and then secondarily screened in other selectin binding assays,

including assays of binding to E-selectin and to L-selectin and in vivo assays. By these means compounds having inhibitory activity for selectin-mediated intercellular adhesion which may be suitable as anti-inflammatory agents may be identified.

EXAMPLE 1CLONING OF THE P-SELECTIN LIGAND PROTEIN GENE5 A. Construction of the HL60 cDNA library

An HL60 cDNA library was constructed for expression cloning the P-selectin ligand. PolyA⁺ RNA was isolated from total RNA from the human promyelocytic cell line HL60 (S.J. Collins, et al., *supra*) using a Fast Track mRNA Isolation Kit (Invitrogen; 10 San Diego, CA). Double stranded cDNA was synthesized from the polyA⁺ RNA fraction and blunt-end ligated with EcoRI adaptors (5'-AATTCGTCGACTCTAGAG-3', 5'-CTCTAGAGTCGACGG-3'). The cDNA was ligated into the expression vector pMT21 (R. Kaufman et al., J. Mol. Cell. Biol. 9, 946-958 (1989) that had been incubated 15 sequentially with EcoRI endonuclease and calf intestinal alkaline phosphatase and gel purified. The ligation product was electroporated in 2 μ l aliquots into competent *E. coli* DH5 α cells and grown in 1 ml of SOB medium (J. Sambrook et al., Molecular Cloning: A Laboratory Manual, New York, Cold Spring Harbor 20 Laboratory Press, p1.90 (1989)) which has been supplemented with 10 mM MgCl₂, 10 mM MgSO₄, and 2 % glycerol for one hour at 37°C. In order to divide the library into smaller subsets, an aliquot from each ml of bacterial suspension was plated onto agar plates in the presence of ampicillin, and the number of colonies per ml 25 was calculated. Assuming that each colony represented one cDNA clone, 600,000 clones were generated and divided into subsets of approximately 16,000 clones per pool. Each of the 38 pools were grown overnight in L-broth in the presence of ampicillin and the plasmids were purified over a CsCl gradient.

30

B. Screening for the P-selectin ligand protein gene

In the first stage, the LEC- γ 1 binding assay of Example 4(A) was utilized to pan the HL60 cDNA library and thereby to enrich for the plasmid of interest. Six μ g of each HL60 cDNA library 35 pool was co-transfected with 2 μ g of α 3/4FT gene (Example 2) into COS cells. Approximately 45 hours post-transfection, the COS cells were lifted from the plates by incubating the cells in

1mM EGTA for 15 min. at 37°C, followed by scraping with cell lifters. The cells were washed twice in Hanks buffered saline solution containing 1mM calcium (HBSS). The cells were resuspended in 4 ml of HBSS. The resuspended transfected COS cells were screened using the LEC- γ 1 binding assay described in Example 4(A).

The plasmids from adherent COS cells were recovered from a Hirts extract [B. Hirts, J. Mol. Biol., 26, 365-369 (1967)] and then electroporated into E. coli DH5 α cells for amplification. The enriched population of plasmids was purified over a CsCl gradient and re-transfected along with the 3/4FT gene (Example 2) into COS cells. The transfection, screening, and plasmid amplification process was repeated for a total of three times before a pool that bound to the LEC- γ 1-coated plates was visually detected. The positive plasmid pool was subsequently broken down into subsets. This involved electroporating the Hirts extract from the positive pool into E. coli DH5 α cells and quantitating colonies per ml as described above. Various pool sizes were produced by plating out a predetermined number of colonies on agar plates in the presence of ampicillin. Duplicate plates were prepared by performing nitrocellulose lifts and storing the filters on new agar plates. The duplicate plates served as reference plates for selecting individual or groups of colonies from any pool identified as being positive.

In the second stage of cloning, COS cells were co-transfected with the sublibrary pools and the 3/4FT gene by the same procedure used in the initial steps of screening. Forty-eight hours post-transfection, the transfected cells were screened using the fluorescent CHO:P-selectin assay of Example 4(B). Positive pools were further subdivided, as described above, until finally individual colonies were screened and positive clones identified. Using this method, a single positive clone, pMT21:PL85, was found to encode the P-selectin ligand protein. The DNA sequence of the P-selectin ligand contained in pMT21:PL85 is set forth in SEQ ID NO:1, and the binding characteristics of the P-selectin ligand protein encoded by pMT21:PL85 are set forth in Example 4(C) below.

EXAMPLE 2CLONING THE α 1,3/1,4 FUCOSYLTRANSFERASE GENE

The α 1,3/1,4 fucosyltransferase gene (3/4FT) was cloned from total human genomic DNA (Clontech Laboratories) by means of PCR. The sense oligonucleotide primer contained an XbaI site and the 5' terminus of the gene (5'-TAGCATACGCTCTAGAGCATGGATCCCCTGGGTGCA

5 GCCAAGC-3'), and the antisense oligonucleotide primer contained an EcoRI site and the 3' terminus of the gene (5'-

10 CCGGAATTCTCAGGTGAA

15 CCAAGCCGC-3'). The PCR product was sequentially digested with XbaI and EcoRI and purified by standard gel purification methods. This gene was then ligated with vector pMT3Sv2ADA (R. Kaufman, Methods in Enzymology, *supra*) that had also been sequentially digested with XbaI and EcoRI and purified by standard gel purification methods. Competent HB101 cells (Biorad) were transformed with this ligation product and then plated on agar plates in the presence of ampicillin. Nitrocellulose filter

20 lifts of ampicillin-resistant transformants were probed with a radiolabeled oligonucleotide (5'-AAGTATCTGTCCAGGGCTTCCAGGT-3') complementary to the nucleotide region 506-530 in the middle of the gene (J. Sambrook et al., *supra*).

Plasmid DNA minipreps were prepared from twelve positive clones. The purified DNA was then digested with EcoRI and XbaI to identify the correct clone with the proper size insert. This clone (pEA.3/4FT) was then grown up large scale and the DNA isolated by CsCl density gradient banding (J. Sambrook et al., *supra*). DNA sequencing confirmed the identity of the 3/4FT gene.

30 The functionality of the gene was assessed in a cell-cell binding assay as follows. COS-1 monkey cells [(clone M6; M. Horwitz et al., Mol. Appl. Genet., 2:147-149, (1983)] were transfected with 3/4FT using DEAE dextran followed by DMSO shock treatment and chloroquine incubation [L. Sompeyrac and K. Dana, Proc. Natl. Acad. Sci., 78:7575-7578 (1981); M. Lopata et al., Nucleic Acids Res., 12:5707-5717, (1984); H. Luthman and G. Magnuson, Nucleic Acids Res., 11:1295-1308, (1983)]. The transfected COS cells

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were suspended and quantitated for binding to a CHO line expressing E-selectin [G. Larsen et al., J. Biol. Chem. 267:11104-11110, (1992)]. This assay confirmed that the COS cells transfected with 3/4FT can express the sialylated Lewis^x epitope on the cell surface.

EXAMPLE 3

EXPRESSION OF THE P-SELECTIN LIGAND PROTEIN

10

A. Expression of the P-selectin Ligand in LEC11 cells

Functional P-selectin ligand was expressed in the SLe^x-positive Chinese hamster ovary (CHO) cell line LEC11 (Campbell, C. and Stanley, P. Cell 35:303-309 (1983) as follows:
approximately 8 µg of plasmid containing the P-selectin ligand gene (pMT21:PL85, Example 1) was transfected into LEC11 cells. At 68 hours post-transfection, the cells were treated with 2.5 mM sodium butyrate for 4 hours. The cells were observed to induce P-selectin adhesion, as determined using the 6-CFD labeled CHO:P-selectin cell binding assay (described in Example 4, section B). In contrast, neither LEC11 cells alone nor LEC11 cells transfected with a control plasmid induced P-selectin adhesion.

B. Expression of Soluble P-Selectin Ligand in COS cells

COS cells were transfected with 8 µg pED.sPSL.T7 (see Example 5C) and 4 µg pEA.3/4 FT plasmid of Example 2, 8 µg pED.sPSL.T7 alone, or 8 µg plasmid vector (pMT21) and 4 µg pEA.3/4 FT gene. Forty-five hr post-transfection, the cells were rinsed twice in PBS and incubated overnight at 37°C in serum-free DMEM minus phenol red (JRH Biosciences) supplemented with 2 mM L-glutamine, 100 U/ml penicillin and 100 µg/ml streptomycin. Phenylmethylsulfonyl fluoride, aprotinin and NaN₃ were added to final concentrations of 1mM, 2 µg/ml and 0.02%, respectively, and the conditioned medium was centrifuged to remove all debris.

For immunoprecipitation experiments, the labeled soluble P-selectin ligand protein was produced by co-transfecting COS cells

with pED.sPSL.T7 and pEA.3/4 FT. At forty-five hr post-transfection, the COS cells were labeled with 250 μ Ci/ml 35 S methionine (NEN) for 5 hours and the medium was collected. Expression of sPSL.T7 protein was confirmed by immunoprecipitation with anti-T7 antibodies.

C. Expression of PACE-cleaved P-selectin ligand in COS Cells

COS cells were co-transfected with the pED.sPSL.T7 plasmid of Example 5(C), the pEA.3/4FT cDNA of Example 2, and a plasmid containing the PACE cDNA as set forth in SEQ ID NO:5. A parallel control co-transfection was done using only the pED.sPSL.T7 plasmid and the pEA.3/4FT plasmid. After 45 hours, conditioned medium from these transfected COS cells was coated onto plastic dishes and binding to CHO:P-selectin cells (Example 4) was determined. An approximately two-fold increase in bound CHO:P-selectin cells was observed for dishes coated with medium containing the P-selectin ligand co-expressed with PACE, as compared with medium containing P-selectin ligand which had not been co-expressed with PACE. Amino acid sequencing of the N-terminus of purified sPSL.T7 protein from the PACE co-transfection showed that all of the ligand had been cleaved at the PACE consensus site (amino acids 38-41 of SEQ ID NO:1). Radiolabeling of co-transfected COS cells with 35 S-methionine and subsequent SDS-polyacrylamide gel electrophoresis and autoradiography showed that comparable quantities of the P-selectin ligand had been secreted in both co-transfections.

D. Expression of the P-selectin Ligand Protein in CHO Cells

A full-length form (amino acids 1-402) of the P-selectin ligand protein was expressed in the CHO(DUKX) cell line (Urlaub & Chasin, Proc. Natl. Acad. Sci. USA 77, 4216-4220 (1980)) as follows: approximately 25 μ g of the pMT21:PL85 plasmid and approximately 8 μ g of the pED.3/4FT (produced by restriction of pEA.3/4FT with EcoRI and XbaI and insertion of the resulting fragment into the pED plasmid) were co-transfected into CHO(DUKX) cells using the calcium phosphate method. Transfectants were selected for resistance to methotrexate. After two weeks,

individual colonies were screened for SLe^x expression by using a conjugate of an anti SLe^x antibody (CSLEX-1, U.S. 4,752,569) and sheep red blood cells (sRBC) prepared by the chromic chloride method (Goding, J. W., J. Immunol. Methods 10:61-66 (1976) as follows: sRBC were washed with 0.15M NaCl until the wash became clear and then a 50% suspension of sRBC was prepared in 0.15M NaCl. One ml of 0.01% chromic chloride solution was added dropwise while vortexing to 0.2 ml of a sRBC suspension containing 50 µg of CSLEX-1. After incubating at 37°C for 30 minutes, 10 ml of phosphate buffered saline (PBS) solution was added to the reaction. The conjugate was washed once before resuspending into 10 ml of PBS. The plates containing transfectants were washed with PBS and then 3 ml of PBS and one ml of the sRBC/CSLEX-1 conjugate was added to each plate. Positive colonies were red on a transilluminator and were picked into alpha medium with 10% fetal bovine serum. After two weeks, colonies were subjected to stepwise amplification using methotrexate at concentrations of 2, 10, 25, 100, 250 nM. The stable cell line obtained was designated CD-PSGL-1 (R3.4). Expression of the P-selectin ligand protein was confirmed by immunoprecipitation studies using the polyclonal anti-P-selectin ligand protein antibody of Example 7(A). The functionality of the P-selectin ligand protein produced by the CD-PSGL-1 (R3.4) cell line was tested by assaying the transfectants for binding to LEC-γ1 as in Example 4(A).

The sPSL.T7 protein was expressed in a stable CHO-PACE line which was already expressing the cDNA encoding PACE as set forth in SEQ ID NO:5 under adenosine deaminase selection (Kaufman, et al., PNAS (USA) 83:3136-3140 (1986)). The psPSL.T7 (25 µg) and pED.3/4FT (8 µg) plasmids were cotransfected into CHO-PACE cells using the calcium phosphate method. Transfectants were selected for resistance to methotrexate, and individual colonies which bound to the sRBC/CSLEX-1 conjugate were picked. After two weeks in culture, the colonies were subjected to stepwise amplification as described above. The stable cell line obtained was designated CP/PSL-T7 (R4.1). Expression of sPSL.T7 protein was confirmed by standard immunoprecipitation methods using either a T7

specific monoclonal antibody or the LEC- γ 1 chimera of Example 4(A). In a similar fashion, a stable cell line expressing the mature full length form (amino acids 42-402) of the P-selectin ligand protein was obtained by co-transfection of pMT21:PL85 and pED.3/4FT into the CHO-PACE line.

Stable cell lines expressing the sPSL.Q protein of Example 5(B) and the sPSL.Fc protein of Example 5(D) were constructed as follows: plasmids pED.sPSL.Q (25 μ g) or pED.sPSL.Fc (25 μ g) were cotransfected with approximately 25 μ g of the pED.3/4FT plasmid described above and approximately 20 μ g of a plasmid containing the PACE cDNA as set forth in SEQ ID NO:5) as well as the neomycin resistance gene into CHO(DUKX) cells using the calcium phosphate method. Transfectants were selected for resistance to methotrexate and the G418 antibiotic. Approximately two weeks later, individual colonies were screened for SLe^x expression using sRBC/CSLEX-1 conjugate binding. The positive colonies were picked in G418 medium at 1 mg/ml concentration. After 2-3 weeks in culture, cells were amplified with methotrexate in a stepwise selection. The stable cell lines obtained were designated CD-sPSL.Q (R8.2) and CD-sPSL.Fc (R8.1), respectively. The expression of sPSL.Q and sPSL.Fc protein was confirmed by standard immunoprecipitation method using the anti P-selectin ligand protein polyclonal antibody of Example 7(A).

EXAMPLE 4

ASSAYS OF P-SELECTIN-MEDIATED INTERCELLULAR ADHESION

A. LEC- γ 1 Binding Assay

A DNA encoding a chimeric form of P-selectin conjugated to the Fc portion of a human IgG γ 1 (LEC- γ 1) was constructed using known methods (Aruffo et al. Cell 67, 35-44 (1991)), and stably transfected into dhfr^r CHO cells (CHO DUKX) for high level production of the chimeric LEC- γ 1 protein, which was purified for use in the binding assay set forth below.

Petri dishes were coated first with a polyclonal anti-human IgG γ 1 Fc antibody and then with LEC- γ 1. This method orients the

LEC- γ 1 construct such that the P-selectin portion of the chimeric molecule is presented on the surface of the plates. Adhesion of HL60 cells to the oriented LEC- γ 1 was quantitated in the presence and absence of calcium. HL60 adhesion was shown to be calcium dependent, confirming that the chimeric molecule had retained functional binding of P-selectin to its ligand on HL60 cells. The binding of HL60 cells to oriented LEC- γ 1 was also shown to be blocked by a neutralizing monoclonal antibody to P-selectin, demonstrating the specificity of P-selectin binding.

B. Fluorescent CHO-P-selectin Binding Assay

The assay employed a fluorescently labeled CHO:P-selectin cell line (Larsen et al., J. Biol. Chem. 267, 11104-11110 (1992)) that can bind to and form clusters on the surface of COS cells that are co-transfected with the P-selectin ligand gene and the 3/4 FT gene. The CHO:P-selectin cells were suspended at 1.5×10^6 cells/ml in 1% fetal bovine serum in DME medium and labeled by adding 6-carboxyfluorescein diacetate (6-CFD) to a final concentration of 100 ug/ml. After incubation at 37°C for 15 minutes, the cells were washed in medium and resuspended at 1×10^5 cells/ml. Five ml of the labeled cells were added to each washed COS transfectant-containing plate to be assayed and incubated at room temperature for 10 minutes. Nonadherent cells were removed by four washes with medium. The plates were then scanned by fluorescence microscopy for rosettes of adherent CHO:P-selectin cells.

C. Quantitative adhesion assay using radioactively labeled CHO:P-selectin cells

COS cells were co-transfected with the pMT21:PL85 plasmid of Example 1 and the pEA.3/4FT plasmid of Example 2 by the same procedure used in the initial stages of screening. As controls, COS cells were transfected with pMT21:PL85 alone, or with pEA.3/4FT alone, or with a similar plasmid containing no insert ("mock"). 24 hours post-transfection, the transfected cells were trypsinized and distributed into Costar 6-well tissue culture plates. CHO:P-selectin cells were labeled for 16 hours with ^3H -thymidine using known methods and preincubated at 0.5×10^6

cells/ml for 30 minutes at 4°C in α medium containing 1% BSA (control); α medium containing 1% BSA, 5 mM EDTA and 5 mM EGTA; α medium containing 1% BSA and 10 μ g/ml of a neutralizing anti P-selectin monoclonal antibody; and α medium containing 1% BSA and a non-neutralizing anti-P-selectin monoclonal antibody. The preincubated cells were then added to the wells containing the transfected COS cells. After a 10 minute incubation, unbound cells were removed by 4 changes of medium. The bound CHO:P-selectin cells were released by trypsinization and quantified by scintillation counting.

COS cells co-transfected with P-selectin ligand and the 3/4FT induced approximately 5.4-fold more binding of CHO:P-selectin cells relative to COS mock cells; assay in the presence of EGTA and EDTA reduced binding to the level of the mock transfected COS cells. Likewise, incubation with neutralizing anti-P-selectin antibody also eliminated specific binding, whereas non-neutralizing antibody had no effect. In contrast, the binding of CHO:P-selectin to COS cells transfected with P-selectin ligand alone was not statistically different than binding to the mock-transfected COS in both the presence or absence of EDTA and EGTA, or anti-P-selectin antibodies. The binding of CHO:P-selectin cells to COS cells transfected with 3/4 FT alone was approximately 2-fold greater than to the mock-transfected COS, but was unaffected by the presence or absence of EDTA and EGTA.

EXAMPLE 5

CONSTRUCTION OF SOLUBLE P-SELECTIN LIGANDS

The EcoRI adaptors used to generate the cDNA library from HL60 cells in Example I contain an XbaI restriction site (TCTAGA) just 5' of the beginning of SEQ ID NO:1 as it is located in the pMT21:PL85 plasmid. In order to generate soluble forms of the PSL, the pMT21:PL85 plasmid was restricted with XbaI and with HincII (which cleaves after nucleotide 944 of SEQ ID NO:1). The approximately 950 bp fragment thus generated, containing all of the encoded extracellular segment of the ligand up to and including the codon for valine 295, was isolated and used to

generate DNAs encoding soluble forms of the P-selectin ligand protein as set forth in sections A through D below.

A. Construction of psPSL.QC

5 The fragment was purified and ligated into mammalian expression vector pED between the XbaI and EcoRI sites, along with double stranded synthetic oligonucleotide DNA that recreated the codons from Asn 296 to Cys 310 and introduced a novel stop codon immediately following Cys 310. The sequence of the oligos is as follows:

5'-AACTACCCAGTGGGAGCACCAGACCACATCTCTGTGAAGCAGTGCTAG

5'-AATTCTAGCACTGCTTCACAGAGATGTGGTCTGGTCTCCCACTGGGTTAGTT

10 The resulting plasmid was designated pED.sPSL.QC, and the protein expressed from the plasmid was designated sPSL.QC.

15

B. Construction of psPSL.Q

The fragment was purified and ligated into the pED plasmid (Kaufman et al., 1991) between the XbaI and EcoRI sites, along with the double stranded synthetic oligonucleotide DNA that recreated the codons from Asn 296 to Gln 309 and introduced a novel stop codon immediately following Gln 309. The sequence of the oligos is as follows:

20 5'-AACTACCCAGTGGGAGCACCAGACCACATCTCTGTGAAGCAGTAG

5'-AATTCTACTGCTTCACAGAGATGTGGTCTGGTCTCCCACTGGGTTAGTT

25 The resulting plasmid was designated pED.sPSL.Q, and the protein expressed from the plasmid was designated sPSL.Q.

C. Construction of psPSL.T7

30 Oligonucleotides encoding 14 amino acids including an epitope derived from the phage T7 major capsid protein were synthesized, creating a C-terminal fusion of the epitope "tag" with an additional 32 amino acids derived from the vector sequence. Two oligonucleotides having the sequences

35 5'-CTAGACCCGGGATGGCATCCATGACAGGAGGACAACAAATGGTAGGCCGCTAG and

5'-AATTCTACGGCCTACCCATTTGTTGTCCTCCTGTCATGGATGCCATCCCGGGT

were duplexed and ligated with the large XbaI-EcoRI fragment of mammalian expression plasmid pED. The resulting plasmid, pED.T7 was restricted with XbaI and SmaI and ligated to the 950 bp XbaI-HincII fragment described above, resulting in plasmid pED.sPSL.T7.

The protein resulting from expression of pED.sPSL.T7 was designated sPSL.T7.

D. Construction of Soluble P-selectin Ligand--IgGFc Chimera

The plasmid DNA encoding a soluble, extracellular form of the P-selectin ligand protein fused to the Fc portion of human immunoglobulin IgG1 was constructed as follows: the mammalian expression vector pED.Fc contains sequences encoding the Fc region of a human IgG1 with a novel linker sequence enabling the fusion of coding sequences amino terminal to the hinge region via a unique XbaI restriction site. A three fragment ligation was performed: pED.Fc was restricted with XbaI and gel purified in linear form. The 950 bp fragment from pMT21:PL85 described above comprised the second fragment. The third fragment consisted of annealed synthetic oligonucleotide DNAs having the following sequence:

5' - CTGCGGCCGCGAGT

5' - CTAGACTGCGGCCGCGAG

The ligation products were grown as plasmid DNAs and individual clones having the correct configuration were identified by DNA sequencing. The plasmid was designated pED.PSL.Fc. The DNA coding region of the resulting soluble P-selectin ligand /Fc fusion protein is shown in SEQ ID NO:6.

EXAMPLE 6

CHARACTERIZATION OF EXPRESSED P-SELECTIN LIGANDS

A. Binding Characterization of Full-Length P-selectin Ligand Protein Expressed on COS Cells

Co-transfection of COS cells with the pEA.3/4FT plasmid of Example 2 and the pMT21:PL85 plasmid of Example 1 yields COS cells which specifically bind to CHO:P-selectin cells. This binding is observed only upon co-transfection of pEA.3/4FT and pMT21:PL85; use of either plasmid alone generates COS cells which

do not bind to CHO:P-selectin cells. No binding is observed between the parental CHO(DUKX) cell line which does not express P-selectin and COS cells co-transfected with pEA.3/4FT and PMT21:PL85. The binding between the co-transfected COS cells and CHO:P-selectin cells is sensitive to chelators of divalent ions such as EDTA and EGTA, consistent with the Ca^{++} dependency of P-selectin mediated cellular adhesion. A neutralizing anti-P-selectin monoclonal antibody blocked the binding between the CHO:P-selectin cells and the COS cells which had been co-transfected with pEA.3/4FT and PMT21:PL85, while a non-neutralizing anti-P-selectin monoclonal antibody had no effect on the binding. The antibody results indicate that the functional domain(s) of P-selectin are required for binding to P-selectin ligand protein expressed on the surface of COS cells.

B. Electrophoretic Characterization of Full-Length P-selectin Ligand Expressed in COS Cells

Detergent extracts of co-transfected COS cells were prepared as follows: 45 hours post co-transfection, approximately 1.5×10^7 cells were suspended in 5 ml of lysis buffer (10mM Piperazine-N,N'-bis[2-ethanesulfonic acid] (PIPES) pH 7.5, 100 mM KCl, 3 mM MgCl_2 , 1 mM benzamidine, 0.5 $\mu\text{g/ml}$ leupeptin, 0.75 $\mu\text{g/ml}$ pepstatin, 1 mM ethylmaleimide, and 1 $\mu\text{g/ml}$ aprotinin) and lysed by sonication. Cellular debris was removed by low speed centrifugation (500 x g, 10 minutes), and a membrane fraction collected by ultracentrifugation (100,000 x g, 60 min). The high speed membrane pellet was resuspended in an extraction buffer (10 mM 3-[N-Morpholino]propanesulfonic acid] (MOPS) pH 7.5, 0.1M NaCl, 0.02% NaN_3 , 1% Thesit® (Sigma), 1 mM benzamidine, 0.5 $\mu\text{g/ml}$ leupeptin, 0.75 $\mu\text{g/ml}$ pepstatin, 1 mM ethylmaleimide, and 1 $\mu\text{g/ml}$ aprotinin). Samples were then subjected to SDS polyacrylamide gel electrophoresis and transfer to nitrocellulose blots as follows: an aliquot of the detergent extract was suspended in 1% SDS loading buffer and heated for 5 minutes at 100°C before loading onto an 8-16% polyacrylamide gel (reduced) or a 6% gel (non-reduced) and electrophoresed in the Laemmli buffer system. Blots were prepared using Immobilon-P® transfer membranes. The blots were immersed in 10 mM MOPS pH 7.5, 0.1M NaCl, 0.02% NaN_3 ,

1 mM MgCl₂, 1 mM CaCl₂, and 10% non-fat milk overnight at 4°C. Blots were rinsed once in the above buffer, minus the milk, and incubated in blotting buffer (10 mM MOPS pH 7.5, 0.1M NaCl, 1% bovine serum albumin, 0.05% Thesit, 1 mM MgCl₂, 1 mM CaCl₂) for 30 minutes at room temperature.

The blots were then probed for the P-selectin ligand as follows: 50 ng of a P-selectin/Fc chimera was pre-incubated with 3 µCi of ¹²⁵I-Protein A in blotting buffer for 30 minutes at room temperature. Additional excipients (e.g., EDTA, EGTA, monoclonal antibodies) could be added to the pre-incubation mixture at this point to evaluate their effects on binding of the chimera to the P-selectin ligand. The pre-incubated mixture was then incubated with the blots (prepared as above) for 60 minutes at room temperature, and the blots were subsequently washed four times with the same blotting buffer (without bovine serum albumin), air dried, and autoradiographed at -70°C.

Under non-reducing conditions, two bands were observed with this technique for membrane extracts prepared from co-transfected COS cells. The major band migrated with an estimated molecular weight of approximately 220 kD, whereas the minor band migrated with a molecular weight of approximately 110 kD. Under reducing conditions, only a single band was observed with a molecular weight of approximately 110 kD, indicating that under non-reducing conditions, the P-selectin ligand exists as a homodimer. The approximate molecular weight of the reduced monomer is greater than that predicted from the deduced amino acid sequence of the cDNA clone (45 kD), indicating that the expressed protein undergoes extensive post-translational modification (see Example 6(C)). The specificity of the P-selectin/Fc chimera was confirmed by the observation that a nonspecific IgG₁ probe yielded no bands on the blots. Additionally, the binding of the P-selectin/Fc chimera to the blots was abolished by EDTA, EGTA, and a neutralizing anti-P-selectin monoclonal antibody. Specific bands on the blots were observed only from membrane extracts of COS cells co-transfected with the pEA.3/4FT and pMT21:PL85 plasmids. Membrane extracts from control transfections

(pEA.3/4FT or pMT21:PL85 alone) failed to yield observable bands on blots.

C. Glycosylation of P-selectin Ligand Protein

5 The presence of covalently attached carbohydrate on
recombinant P-selectin ligand and its role in binding to P-
selectin was determined as follows: COS cells were co-
transfected with pED.sPSL.T7 of Example 5(C) and the pEA.3/4FT
10 plasmid of Example 2. After 48 hours, the cells were pulsed with
³⁵S-methionine. 200 μ l of ³⁵S methionine-labeled sPSL.T7
conditioned medium was incubated with 5 μ g LEC- γ 1 in the presence
of 2mM CaCl₂ and 1 mg/ml bovine serum albumin (BSA). After
rotating for 2 hours at 4°C, Protein A-Sepharose beads
15 (Pharmacia) were added for 1 hour at 4°C, pelleted by
centrifugation and washed twice in Tris buffered saline (20 mM
Tris-HCl, 150 mM NaCl pH 7.5, hereinafter TBS) containing 2mM
CaCl₂ and 1 mg/ml BSA. The pellets were then resuspended and
treated with neuraminidase (*Streptococcus pneumoniae*), O-
glycanase, and N-glycanase (all from Genzyme) as follows. All
20 glycosidase digestions were done at 37°C overnight. For
neuraminidase digestion, the pellet was resuspended in 50 μ l 2-
(N-morpholino)-ethanesulfonic acid (MES) buffer, pH 6.5
(Calbiochem) and 0.1% SDS, heated at 95°C for 5 minutes, then
pelleted. The supernatant was modified to contain 1.4% n-Octyl
25 B-D-glucopyranoside (OGP), 10mM calcium acetate, 20 mM sodium
cacodylate and 2.5 mM PMSF, final pH 7.0 Eight μ l neuraminidase
was added for a final concentration of 1 unit/ml. For
neuraminidase/O-glycanase digestion, the sample was prepared as
above and along with the neuraminidase, the O-glycanase was also
30 added to a final concentration of 0.1 unit/ml. For N-glycanase
digestion, the pellet was resuspended in 54 μ l MES buffer and 1%
SDS, heated at 95°C for 5 minutes, then pelleted. The
supernatant was modified to contain 0.2 M sodium phosphate, 3.5%
OGP, and 2.5 mM PMSF, final pH 8.5. N-glycanase was added for
35 a final concentration of 12 units/ml and incubated as above.

The effect of glycosidase treatment on sPSL.T7 was assessed
in two ways. For this, each digested protein sample was divided

into two equal fractions. One fraction was precipitated with the P-selectin polyclonal antibody of Example 7(A), to show the effect of digestion on the electrophoretic mobility. The other fraction was precipitated with the LEC- γ 1 chimera of Example 4(A), to assess the remaining P-selectin ligand binding activity after digestion. The immunoprecipitated samples were analyzed by SDS-polyacrylamide gel electrophoresis under reducing conditions and autoradiography.

In the absence of glycosidase treatment, autoradiography revealed comparable bands (with molecular weights of 110 kD) for each precipitation. When the P-selectin ligand protein was treated with neuraminidase, anti-P-selectin ligand polyclonal antibody precipitation revealed a slight decrease in mobility, consistent with removal of sialic acid residues. The amount of P-selectin ligand protein precipitated by LEC- γ 1 was significantly reduced after neuraminidase treatment, consistent with the role of sialic acid residues in the P-selectin/P-selectin ligand interaction. When the P-selectin ligand protein was treated with both neuraminidase and O-glycanase, a substantial increase in electrophoretic mobility was observed after precipitation with the anti-P-selectin ligand polyclonal antibody, indicating that a number of O-linked oligosaccharide chains had been removed. However, removal of O-linked oligosaccharides from the P-selectin ligand protein may not have been complete, since the electrophoretic mobility did not correspond to a protein with a molecular weight of 38 kD, as would be predicted from the amino acid sequence set forth in SEQ ID NO:1. The neuraminidase/O-glycanase digested P-selectin ligand protein bound to LEC- γ 1 very poorly, further indicating the role of oligosaccharides in the P-selectin/P-selectin ligand interaction. Treatment of the purified P-selectin ligand with N-glycanase resulted in a slight increase in electrophoretic mobility, demonstrating that some of the consensus sites for N-linked glycosylation are occupied. The amount of P-selectin ligand protein precipitated by LEC- γ 1 was slightly reduced, indicating that N-linked glycosylation also contributes to the

P-selectin/P-selectin ligand interaction, though not as dramatically as sialylation and O-linked glycosylation.

EXAMPLE 7

POLYCLONAL ANTIBODIES-SPECIFIC-FOR P-SELECTIN LIGANDS

5

A. Polyclonal Rabbit anti-P-selectin Ligand Protein/Maltose Binding Protein Fusion Protein

10 The anti-P-selectin ligand polyclonal antibody was generated by immunizing rabbits with a fusion protein generated in *E. coli*. The fusion protein consisted of the amino terminal one-third of the P-selectin ligand (amino acids 1 to 110 of SEQ ID NO:1) fused in frame to the maltose binding protein (Maina, C. V. et al., Gene 74, 365-373 (1988); Riggs, P., in Current Protocols in
15 Molecular Biology, F. M. Ausubel et al., Eds., Greene Associates/Wiley Interscience (New York, 1990) chapter 16.6). Under conditions employed herein, the fusion protein antibody recognizes the P-selectin ligand protein.

20 B. Polyclonal Rabbit Anti-sPSL.T7 Protein

A soluble form of the invention (sPSL.T7; see example 5(C)) was purified to apparent homogeneity according to the following scheme: COS cells were transfected with three plasmids, one encoding each of the following: sPSL.T7 (Example 5(C)), 3/4FT (Example 2), and a soluble form of PACE (as set forth in SEQ ID
25 NO:5). After 72 hours, the conditioned medium was collected and recombinant sPSL.T7 was purified as follows.

Conditioned medium was diluted two fold with 50 mM MOPS, 150 mM NaCl, 0.5 mM CaCl₂ and 0.5 mM MnCl₂, pH 7.2, and applied to a
30 column of lentil lectin-Sepharose 4B equilibrated in the same buffer. After loading, the column was washed with the same buffer until the optical absorbance at 280 nm dropped to a stable baseline. The column was then eluted with the same buffer which had been adjusted to 0.5 M α -methyl-mannoside and 0.3 M NaCl.
35 Recombinant sPSL.T7 was collected over 5-15 column volumes of this elution buffer. The lentil lectin eluate was then subjected to a 0-70% ammonium sulfate precipitation by adding 472g of ammonium sulfate per liter of column eluate at 4°C. After

stirring for 30 minutes, the precipitate was resuspended in a minimal volume of TBS (20 mM Tris-HCl, 150 mM NaCl, pH 7.5) and applied to a TSK G4000SW_{XL} gel filtration column equilibrated in TBS. The flow rate on the column was 0.5 ml/min and a guard column was employed. In aliquots of < 250 μ l, the resuspended ammonium sulfate pellet was injected on the column and fractions analyzed by SDS-PAGE with Western analysis. Fractions containing SPLS.T7 were pooled and then used for immunizing rabbits.

Antibodies to SPLS.T7 were generated in the standard fashion by antigen priming and subsequent boosting over a 3 month period. Specifically, primary immunization was performed by mixing 50 μ g of SPLS.T7 (denatured by mixing in 0.1% SDS and heating for 10 minutes at 100°C) with complete Freund's adjuvant and injected at five sites subcutaneously. The second (and all subsequent) boosts were performed by mixing 25 μ g of SPLS.T7 (denatured by mixing in 0.1% SDS and heating for 10 minutes at 100°C) [12.5 μ g for the third and subsequent boosts] with incomplete Freund's adjuvant and injecting at two sites subcutaneously (or later, intramuscularly) every two weeks. Test bleeds were performed every two weeks to monitor antibody titer. When the antibody titer reached a suitable level, a larger scale bleed was performed and a total serum fraction prepared. This polyclonal antibody preparation was used to inhibit the specific binding of HL60 cells to CHO:P-selectin cells in a manner similar to that described in Example 4.

This assay employed fluorescently-labeled HL60 cells (labelled with BCECFAM; 2',7'-bis-(2-carboxymethyl)-5-(and-6)-carboxyfluorescein, acetoxymethyl ester) binding to CHO cells plated on the bottom of microtiter plates. The labelled HL60 cells were pre-incubated with either sera containing polyclonal antibody or with pre-immune sera for 30 minutes at 4°C. The cells were then washed and incubated with the CHO:P-selectin cells for 10 minutes. The plates were then washed and the fluorescence read with a fluorescence microtiter plate reader. Using this assay, a 1:15 dilution of the anti-SPLS.T7 polyclonal serum resulted in essentially complete inhibition of HL60 cell binding to CHO:P-selectin. Demonstrable inhibition of HL60

binding to CHO:P-selectin was still observed at antiserum dilutions of 1:150. Pre-immune serum had no effect on HL60 cell binding to CHO:P-selectin.

SEQUENCE LISTING

5 (1) GENERAL INFORMATION:

(i) APPLICANT: GENETICS INSTITUTE, INC.

10 (ii) TITLE OF INVENTION: NOVEL P-SELECTIN LIGAND PROTEIN

(iii) NUMBER OF SEQUENCES: 6

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20 (v) COMPUTER READABLE FORM:

25 (A) MEDIUM TYPE: Floppy disk
(B) COMPUTER: IBM PC compatible
(C) OPERATING SYSTEM: PC-DOS/MS-DOS
(D) SOFTWARE: PatentIn Release #1.0, Version #1.25

(vi) CURRENT APPLICATION DATA:

30 (A) APPLICATION NUMBER:
(B) FILING DATE:
(C) CLASSIFICATION:

(vii) PRIOR APPLICATION DATA:

35 (A) APPLICATION NUMBER: US 07/965,662
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(D) FILING DATE: 26-AUG-1993

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(2) INFORMATION FOR SEQ ID NO:1:

50 (i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 1649 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

55 (ii) MOLECULE TYPE: cDNA

(vi) ORIGINAL SOURCE:

(A) ORGANISM: Homo sapiens
 (G) CELL TYPE: Promyelocyte
 (H) CELL LINE: HL60

5

~~(vii) IMMEDIATE SOURCE:~~

(B) CLONE: pMT21:PL85

(ix) FEATURE:

10

(A) NAME/KEY: 5'UTR
 (B) LOCATION: 1..59

(ix) FEATURE:

15

(A) NAME/KEY: CDS
 (B) LOCATION: 60..1268

(ix) FEATURE:

20

(A) NAME/KEY: 3'UTR
 (B) LOCATION: 1269..1649

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

25	GCCACTTCTT CTGGGCCCAC GAGGCAGCTG TCCCATGCTC TGCTGAGCAC GGTGGTGCC	59
	ATG CCT CTG CAA CTC CTC CTG TTG CTG ATC CTA CTG GGC CCT GGC AAC	107
	Met Pro Leu Gln Leu Leu Leu Leu Ile Leu Leu Gly Pro Gly Asn	
	1 5 10 15	
30	AGC TTG CAG CTG TGG GAC ACC TGG GCA GAT GAA GCC GAG AAA GCC TTG	155
	Ser Leu Gln Leu Trp Asp Thr Trp Ala Asp Glu Ala Glu Lys Ala Leu	
	20 25 30	
35	GGT CCC CTG CTT GCC CGG GAC CGG AGA CAG GCC ACC GAA TAT GAG TAC	203
	Gly Pro Leu Leu Ala Arg Asp Arg Arg Gln Ala Thr Glu Tyr Glu Tyr	
	35 40 45	
40	CTA GAT TAT GAT TTC CTG CCA GAA ACG GAG CCT CCA GAA ATG CTG AGG	251
	Leu Asp Tyr Asp Phe Leu Pro Glu Thr Glu Pro Pro Glu Met Leu Arg	
	50 55 60	
45	AAC AGC ACT GAC ACC ACT CCT CTG ACT GGG CCT GGA ACC CCT GAG TCT	299
	Asn Ser Thr Asp Thr Thr Pro Leu Thr Gly Pro Gly Thr Pro Glu Ser	
	65 70 75 80	
50	ACC ACT GTG GAG CCT GCT GCA AGG CGT TCT ACT GGC CTG GAT GCA GGA	347
	Thr Thr Val Glu Pro Ala Ala Arg Arg Ser Thr Gly Leu Asp Ala Gly	
	85 90 95	
55	GGG GCA GTC ACA GAG CTG ACC ACG GAG CTG GCC AAC ATG GGG AAC CTG	395
	Gly Ala Val Thr Glu Leu Thr Thr Glu Leu Ala Asn Met Gly Asn Leu	
	100 105 110	
60	TCC ACG GAT TCA GCA GCT ATG GAG ATA CAG ACC ACT CAA CCA GCA GCC	443
	Ser Thr Asp Ser Ala Ala Met Glu Ile Gln Thr Thr Gln Pro Ala Ala	
	115 120 125	
60	ACG GAG GCA CAG ACC ACT CCA CTG GCA GCC ACA GAG GCA CAG ACA ACT	491
	Thr Glu Ala Gln Thr Thr Pro Leu Ala Ala Thr Glu Ala Gln Thr Thr	
	130 135 140	

	CGA CTG ACG GCC ACG GAG GCA CAG ACC ACT CCA CTG GCA GCC ACA GAG	539
	Arg Leu Thr Ala Thr Glu Ala Gln Thr Thr Pro Leu Ala Ala Thr Glu	
	145 150 155 160	
5	GCA CAG ACC ACT CCA CCA GCA GCC ACG GAA GCA CAG ACC ACT CAA CCC	587
	Ala Gln Thr Thr Pro Pro Ala Ala Thr Glu Ala Gln Thr Thr Gln Pro	
	165 170 175	
10	ACA GGC CTG GAG GCA CAG ACC ACT GCA CCA GCA GCC ATG GAG GCA CAG	635
	Thr Gly Leu Glu Ala Gln Thr Thr Ala Pro Ala Ala Met Glu Ala Gln	
	180 185 190	
15	ACC ACT GCA CCA GCA GCC ATG GAA GCA CAG ACC ACT CCA CCA GCA GCC	683
	Thr Thr Ala Pro Ala Ala Met Glu Ala Gln Thr Thr Pro Pro Ala Ala	
	195 200 205	
20	ATG GAG GCA CAG ACC ACT CAA ACC ACA GCC ATG GAG GCA CAG ACC ACT	731
	Met Glu Ala Gln Thr Thr Gln Thr Thr Ala Met Glu Ala Gln Thr Thr	
	210 215 220	
25	GCA CCA GAA GCC ACG GAG GCA CAG ACC ACT CAA CCC ACA GCC ACG GAG	779
	Ala Pro Glu Ala Thr Glu Ala Gln Thr Thr Gln Pro Thr Ala Thr Glu	
	225 230 235 240	
30	GCA CAG ACC ACT CCA CTG GCA GCC ATG GAG GCC CTG TCC ACA GAA CCC	827
	Ala Gln Thr Thr Pro Leu Ala Ala Met Glu Ala Leu Ser Thr Glu Pro	
	245 250 255	
35	AGT GCC ACA GAG GCC CTG TCC ATG GAA CCT ACT ACC AAA AGA GGT CTG	875
	Ser Ala Thr Glu Ala Leu Ser Met Glu Pro Thr Thr Lys Arg Gly Leu	
	260 265 270	
40	TTC ATA CCC TTT TCT GTG TCC TCT GTT ACT CAC AAG GGC ATT CCC ATG	923
	Phe Ile Pro Phe Ser Val Ser Ser Val Thr His Lys Gly Ile Pro Met	
	275 280 285	
45	GCA GCC ACC AAT TTG TCC GTC AAC TAC CCA GTG GGG GCC CCA GAC CAC	971
	Ala Ala Ser Asn Leu Ser Val Asn Tyr Pro Val Gly Ala Pro Asp His	
	290 295 300	
50	ATC TCT GTG AAG CAG TGC CTG CTG GCC ATC CTA ATC TTG GCG CTG GTG	1019
	Ile Ser Val Lys Gln Cys Leu Leu Ala Ile Leu Ile Leu Ala Leu Val	
	305 310 315 320	
55	GCC ACT ATC TTC TTC GTG TGC ACT GTG GTG CTG GCG GTC CGC CTC TCC	1067
	Ala Thr Ile Phe Phe Val Cys Thr Val Leu Ala Val Arg Leu Ser	
	325 330 335	
60	CGC AAG GGC CAC ATG TAC CCC GTG CGT AAT TAC TCC CCC ACC GAG ATG	1115
	Arg Lys Gly His Met Tyr Pro Val Arg Asn Tyr Ser Pro Thr Glu Met	
	340 345 350	
65	GTC TGC ATC TCA TCC CTG TTG CCT GAT GGG GGT GAG GGG CCC TCT GCC	1163
	Val Cys Ile Ser Ser Leu Leu Pro Asp Gly Gly Glu Gly Pro Ser Ala	
	355 360 365	
70	ACA GCC AAT GGG GGC CTG TCC AAG GCC AAG AGC CCG GGC CTG ACG CCA	1211
	Thr Ala Asn Gly Gly Leu Ser Lys Ala Lys Ser Pro Gly Leu Thr Pro	
	370 375 380	
75	GAG CCC AGG GAG GAC CGT GAG GGG GAT GAC CTC ACC CTG CAC AGC TTC	1259
	Glu Pro Arg Glu Asp Arg Glu Gly Asp Asp Leu Thr Leu His Ser Phe	
	385 390 395 400	
80	CTC CCT TAGCTCACTC TGCCATCTGT TTTGGCAAGA CCCACCTCC ACGGGCTCTC	1315
	Leu Pro	

CTGGGCCACC CCTGAGTGCC CAGACCCCAA TCCACAGCTC TGGGCTTCCT CGGAGACCCC 1375
 TGGGGATGGG GATCTTCAGG GAAGGAACTC TGGCCACCCA AACAGGACAA GAGCAGCCTG 1435
 5 GGGCCAAGCA GACGGGCAAG TGGAGCCACC TCTTTCTCC CTCCGCGGAT GAAGCCCAGC 1495
 CACATTTTCA CCGAGGTCCA AGGCAGGAGG CCATTTACTT GAGACAGATT CTCTCCTTTT 1555
 10 TCCTGTCCCC CATCTTCTCT GGGTCCCTCT AACATCTCCC ATGGCTCTCC CCGCTTCTCC 1615
 TGGTCACTGG AGTCTCTCTCC CCATGTACCC AAGG 1649

(2) INFORMATION FOR SEQ ID NO:2:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 402 amino acids
 (B) TYPE: amino acid
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:

25 Met Pro Leu Gln Leu Leu Leu Leu Ile Leu Leu Gly Pro Gly Asn
 1 5 10 15
 30 Ser Leu Gln Leu Trp Asp Thr Trp Ala Asp Glu Ala Glu Lys Ala Leu
 20 25 30
 35 Gly Pro Leu Leu Ala Arg Asp Arg Arg Gln Ala Thr Glu Tyr Glu Tyr
 35 40 45
 40 Leu Asp Tyr Asp Phe Leu Pro Glu Thr Glu Pro Pro Glu Met Leu Arg
 50 55 60
 45 Asn Ser Thr Asp Thr Thr Pro Leu Thr Gly Pro Gly Thr Pro Glu Ser
 65 70 75 80
 50 Thr Thr Val Glu Pro Ala Ala Arg Arg Ser Thr Gly Leu Asp Ala Gly
 85 90 95
 55 Gly Ala Val Thr Glu Leu Thr Thr Glu Leu Ala Asn Met Gly Asn Leu
 100 105 110
 Ser Thr Asp Ser Ala Ala Met Glu Ile Gln Thr Thr Gln Pro Ala Ala
 115 120 125

Thr Glu Ala Gln Thr Thr Pro Leu Ala Ala Thr Glu Ala Gln Thr Thr
 130 135 140

5 Arg Leu Thr Ala Thr Glu Ala Gln Thr Thr Pro Leu Ala Ala Thr Glu
 145 150 155 160

10 Ala Gln Thr Thr Pro Pro Ala Ala Thr Glu Ala Gln Thr Thr Gln Pro
 165 170 175

15 Thr Gly Leu Glu Ala Gln Thr Thr Ala Pro Ala Ala Met Glu Ala Gln
 180 185 190

Thr Thr Ala Pro Ala Ala Met Glu Ala Gln Thr Thr Pro Pro Ala Ala
 195 200 205

20 Met Glu Ala Gln Thr Thr Gln Thr Thr Ala Met Glu Ala Gln Thr Thr
 210 215 220

25 Ala Pro Glu Ala Thr Glu Ala Gln Thr Thr Gln Pro Thr Ala Thr Glu
 225 230 235 240

30 Ala Gln Thr Thr Pro Leu Ala Ala Met Glu Ala Leu Ser Thr Glu Pro
 245 250 255

35 Ser Ala Thr Glu Ala Leu Ser Met Glu Pro Thr Thr Lys Arg Gly Leu
 260 265 270

Phe Ile Pro Phe Ser Val Ser Ser Val Thr His Lys Gly Ile Pro Met
 275 280 285

40 Ala Ala Ser Asn Leu Ser Val Asn Tyr Pro Val Gly Ala Pro Asp His
 290 295 300

45 Ile Ser Val Lys Gln Cys Leu Leu Ala Ile Leu Ile Leu Ala Leu Val
 305 310 315 320

Ala Thr Ile Phe Phe Val Cys Thr Val Val Leu Ala Val Arg Leu Ser
 325 330 335

50 Arg Lys Gly His Met Tyr Pro Val Arg Asn Tyr Ser Pro Thr Glu Met
 340 345 350

55 Val Cys Ile Ser Ser Leu Leu Pro Asp Gly Gly Glu Gly Pro Ser Ala

355

360

365

5 Thr Ala Asn Gly Gly Leu Ser Lys Ala Lys Ser Pro Gly Leu Thr Pro
 370 375 380

10 Glu Pro Arg Glu Asp Arg Glu Gly Asp Asp Leu Thr Leu His Ser Phe
 385 390 395 400
 Leu Pro

15 (2) INFORMATION FOR SEQ ID NO:3:

(i) SEQUENCE CHARACTERISTICS:

20 (A) LENGTH: 1239 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA (synthetic)

25 (vi) ORIGINAL SOURCE:

(A) ORGANISM: Homo sapiens
 (G) CELL TYPE: placenta

30 (ix) FEATURE:

(A) NAME/KEY: CDS
 (B) LOCATION: 1..1239

35 (xi) SEQUENCE DESCRIPTION: SEQ ID NO:3:

ATG CCT CTG CAA CTC CTC CTG TTG CTG ATC CTA CTG GGC CCT GGC AAC 48
 Met Pro Leu Gln Leu Leu Leu Leu Ile Leu Leu Gly Pro Gly Asn
 1 5 10 15

40 AGC TTG CAG CTG TGG GAC ACC TGG GCA GAT GAA GCC GAG AAA GCC TTG 96
 Ser Leu Gln Leu Trp Asp Thr Trp Ala Asp Glu Ala Glu Lys Ala Leu
 20 25 30

45 GGT CCC CTG CTT GCC CGG GAC CGG AGA CAG GCC ACC GAA TAT GAG TAC 144
 Gly Pro Leu Leu Ala Arg Asp Arg Arg Gln Ala Thr Glu Tyr Glu Tyr
 35 40 45

50 CTA GAT TAT GAT TTC CTG CCA GAA ACG GAG CCT CCA GAA ATG CTG AGG 192
 Leu Asp Tyr Asp Phe Leu Pro Glu Thr Glu Pro Pro Glu Met Leu Arg
 50 55 60

55 AAC AGC ACT GAC ACC ACT CCT CTG ACT GGG CCT GGA ACC CCT GAG TCT 240
 Asn Ser Thr Asp Thr Thr Pro Leu Thr Gly Pro Gly Thr Pro Glu Ser
 65 70 75 80

60 ACC ACT GTG GAG CCT GCT GCA AGG CGT TCT ACT GGC CTG GAT GCA GGA 288
 Thr Thr Val Glu Pro Ala Ala Arg Arg Ser Thr Gly Leu Asp Ala Gly
 85 90 95

	GGG GCA GTC ACA GAG CTG ACC ACG GAG CTG GCC AAC ATG GGG AAC CTG Gly Ala Val Thr Glu Leu Thr Thr Glu Leu Ala Asn Met Gly Asn Leu 100 105 110	336
5	TCC ACG GAT TCA GCA GCT ATG GAG ATA CAG ACC ACT CAA CCA GCA GCC Ser Thr Asp Ser Ala Ala Met Glu Ile Gln Thr Thr Gln Pro Ala Ala 115 120 125	384
10	ACG GAG GCA CAG ACC ACT CAA CCA GTG CCC ACG GAG GCA CAG ACC ACT Thr Glu Ala Gln Thr Thr Gln Pro Val Pro Thr Glu Ala Gln Thr Thr 130 135 140	432
15	CCA CTG GCA GCC ACA GAG GCA CAG ACA ACT CGA CTG ACG GCC ACG GAG Pro Leu Ala Ala Thr Glu Ala Gln Thr Thr Arg Leu Thr Ala Thr Glu 145 150 155 160	480
20	GCA CAG ACC ACT CCA CTG GCA GCC ACA GAG GCA CAG ACC ACT CCA CCA Ala Gln Thr Thr Pro Leu Ala Ala Thr Glu Ala Gln Thr Thr Pro Pro 165 170 175	528
25	GCA GCC ACG GAA GCA CAG ACC ACT CAA CCC ACA GGC CTG GAG GCA CAG Ala Ala Thr Glu Ala Gln Thr Thr Gln Pro Thr Gly Leu Glu Ala Gln 180 185 190	576
30	ACC ACT GCA CCA GCA GCC ATG GAG GCA CAG ACC ACT GCA CCA GCA GCC Thr Thr Ala Pro Ala Ala Met Glu Ala Gln Thr Thr Ala Pro Ala Ala 195 200 205	624
35	ATG GAA GCA CAG ACC ACT CCA CCA GCA GCC ATG GAG GCA CAG ACC ACT Met Glu Ala Gln Thr Thr Pro Pro Ala Ala Met Glu Ala Gln Thr Thr 210 215 220	672
40	CAA ACC ACA GCC ATG GAG GCA CAG ACC ACT GCA CCA GAA GCC ACG GAG Gln Thr Thr Ala Met Glu Ala Gln Thr Thr Ala Pro Glu Ala Thr Glu 225 230 235 240	720
45	GCA CAG ACC ACT CAA CCC ACA GCC ACG GAG GCA CAG ACC ACT CCA CTG Ala Gln Thr Thr Gln Pro Thr Ala Thr Glu Ala Gln Thr Thr Pro Leu 245 250 255	768
50	GCA GCC ATG GAG GCC CTG TCC ACA GAA CCC AGT GCC ACA GAG GCC CTG Ala Ala Met Glu Ala Leu Ser Thr Glu Pro Ser Ala Thr Glu Ala Leu 260 265 270	816
55	TCC ATG GAA CCT ACT ACC AAA AGA GGT CTG TTC ATA CCC TTT TCT GTG Ser Met Glu Pro Thr Thr Lys Arg Gly Leu Phe Ile Pro Phe Ser Val 275 280 285	864
60	TCC TCT GTT ACT CAC AAG GGC ATT CCC ATG GCA GCC AGC AAT TTG TCC Ser Ser Val Thr His Lys Gly Ile Pro Met Ala Ala Ser Asn Leu Ser 290 295 300	912
65	GTC AAC TAC CCA GTG GGG GCC CCA GAC CAC ATC TCT GTG AAG CAG TGC Val Asn Tyr Pro Val Gly Ala Pro Asp His Ile Ser Val Lys Gln Cys 305 310 315 320	960
70	CTG CTG GCC ATC CTA ATC TTG GCG CTG GTG GCC ACT ATC TTC TTC GTG Leu Leu Ala Ile Leu Ile Leu Ala Leu Val Ala Thr Ile Phe Phe Val 325 330 335	1008
75	TGC ACT GTG GTG CTG GCG GTC CGC CTC TCC CGC AAG GGC CAC ATG TAC Cys Thr Val Val Leu Ala Val Arg Leu Ser Arg Lys Gly His Met Tyr 340 345 350	1056
80	CCC GTG CGT AAT TAC TCC CCC ACC GAG ATG GTC TGC ATC TCA TCC CTG Pro Val Arg Asn Tyr Ser Pro Thr Glu Met Val Cys Ile Ser Ser Leu 355 360 365	1104

TTG CCT GAT GGG GGT GAG GGG CCC TCT GCC ACA GCC AAT GGG GGC CTG 1152
 Leu Pro Asp Gly Gly Glu Gly Pro Ser Ala Thr Ala Asn Gly Gly Leu
 370 375 380
 5 TCC AAG GCC AAG AGC CCG GGC CTG ACG CCA GAG CCC AGG GAG GAC CGT 1200
 Ser Lys Ala Lys Ser Pro Gly Leu Thr Pro Glu Pro Arg Glu Asp Arg
 385 390 395 400
 10 GAG GGG GAT GAC CTC ACC CTG CAC AGC TTC CTC CCT TAG 1239
 Glu Gly Asp Asp Leu Thr Leu His Ser Phe Leu Pro
 405 410

(2) INFORMATION FOR SEQ ID NO:4:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 412 amino acids

(B) TYPE: amino acid

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:4:

25 Met Pro Leu Gln Leu Leu Leu Leu Ile Leu Leu Gly Pro Gly Asn
 1 5 10 15
 30 Ser Leu Gln Leu Trp Asp Thr Trp Ala Asp Glu Ala Glu Lys Ala Leu
 20 25 30
 35 Gly Pro Leu Leu Ala Arg Asp Arg Arg Gln Ala Thr Glu Tyr Glu Tyr
 35 40 45
 40 Leu Asp Tyr Asp Phe Leu Pro Glu Thr Glu Pro Pro Glu Met Leu Arg
 50 55 60
 45 Asn Ser Thr Asp Thr Thr Pro Leu Thr Gly Pro Gly Thr Pro Glu Ser
 65 70 75 80
 50 Thr Thr Val Glu Pro Ala Ala Arg Arg Ser Thr Gly Leu Asp Ala Gly
 85 90 95
 55 Gly Ala Val Thr Glu Leu Thr Thr Glu Leu Ala Asn Met Gly Asn Leu
 100 105 110
 Ser Thr Asp Ser Ala Ala Met Glu Ile Gln Thr Thr Gln Pro Ala Ala
 115 120 125

Thr Glu Ala Gln Thr Thr Gln Pro Val Pro Thr Glu Ala Gln Thr Thr
 130 135 140

5 Pro Leu Ala Ala Thr Glu Ala Gln Thr Thr Arg Leu Thr Ala Thr Glu
 145 150 155 160

Ala Gln Thr Thr Pro Leu Ala Ala Thr Glu Ala Gln Thr Thr Pro Pro
 165 170 175

10 Ala Ala Thr Glu Ala Gln Thr Thr Gln Pro Thr Gly Leu Glu Ala Gln
 180 185 190

15 Thr Thr Ala Pro Ala Ala Met Glu Ala Gln Thr Thr Ala Pro Ala Ala
 195 200 205

20 Met Glu Ala Gln Thr Thr Pro Pro Ala Ala Met Glu Ala Gln Thr Thr
 210 215 220

25 Gln Thr Thr Ala Met Glu Ala Gln Thr Thr Ala Pro Glu Ala Thr Glu
 225 230 235 240

Ala Gln Thr Thr Gln Pro Thr Ala Thr Glu Ala Gln Thr Thr Pro Leu
 245 250 255

30 Ala Ala Met Glu Ala Leu Ser Thr Glu Pro Ser Ala Thr Glu Ala Leu
 260 265 270

35 Ser Met Glu Pro Thr Thr Lys Arg Gly Leu Phe Ile Pro Phe Ser Val
 275 280 285

40 Ser Ser Val Thr His Lys Gly Ile Pro Met Ala Ala Ser Asn Leu Ser
 290 295 300

Val Asn Tyr Pro Val Gly Ala Pro Asp His Ile Ser Val Lys Gln Cys
 305 310 315 320

45 Leu Leu Ala Ile Leu Ile Leu Ala Leu Val Ala Thr Ile Phe Phe Val
 325 330 335

50 Cys Thr Val Val Leu Ala Val Arg Leu Ser Arg Lys Gly His Met Tyr
 340 345 350

55 Pro Val Arg Asn Tyr Ser Pro Thr Glu Met Val Cys Ile Ser Ser Leu
 355 360 365

Leu Pro Asp Gly Gly Glu Gly Pro Ser Ala Thr Ala Asn Gly Gly Leu
 370 375 380

5 Ser Lys Ala Lys Ser Pro Gly Leu Thr Pro Glu Pro Arg Glu Asp Arg
 385 390 395 400

Glu Gly Asp Asp Leu Thr Leu His Ser Phe Leu Pro
 405 410

10

(2) INFORMATION FOR SEQ ID NO:5:

(i) SEQUENCE CHARACTERISTICS:
 15 (A) LENGTH: 2151 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: linear

20 (ii) MOLECULE TYPE: cDNA

(vii) IMMEDIATE SOURCE:
 25 (B) CLONE: pacesol

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:5:

30	ATGGAGCTGA GGCCCTGGTT GCTATGGGTG GTAGCAGCAA CAGGAACCTT GGTCCTGCTA	60
	GCAGCTGATG CTCAGGGCCA GAAGGTCTTC ACCAACACGT GGGCTGTGCG CATCCCTGGA	120
	GGCCCAGCGG TGGCCAACAG TGTGGCACGG AAGCATGGGT TCCTCAACCT GGGCCAGATC	180
35	TTCGGGGACT ATTACCACTT CTGGCATCGA GGAGTGACGA AGCGGTCCCT GTCCGCTCAC	240
	CGCCCGCGGC ACAGCCGGCT GCAGAGGGAG CCTCAAGTAC AGTGGCTGGA ACAGCAGGTG	300
40	GCAAAGCGAC GGAATAAAGC GGACGTGTAC CAGGAGCCCA CAGACCCCAA GTTTCCTCAG	360
	CAGTGGTACC TGTCTGGTGT CACTCAGCGG GACCTGAATG TGAAGGCGGC CTGGGCGCAG	420
	GGCTACACAG GGCACGGCAT TGTGGTCTCC ATTCTGGACG ATGGCATCGA GAAGAACCAC	480
45	CCGGACTTGG CAGGCAATTA TGATCCTGGG CCCAGTTTGT ATGTCAATGA CCAGGACCCT	540
	GACCCCCAGC CTCGGTACAC ACAGATGAAT GACAACAGGC ACGGCACACG GTGTGCGGGG	600
50	GAAGTGGCTG CGGTGGCCAA CAACGGTGTC TGTGGTGTAG GTGTGGCCTA CAACGCCCCG	660
	ATTGGAGGGG TGCGCATGCT GGATGGCGAG GTGACAGATG CAGTGGAGGC ACGCTCGCTG	720
	GGCCTGAACC CCAACCACAT CCACATCTAC AGTGCCAGCT GGGGCCCCGA GGATGACGGC	780
55	AAGACAGTGG ATGGGCCAGC CCGCCTCGCC GAGGAGGCCT TCTTCCGTGG GGTAGCCAG	840
	GGCCGAGGGG GGCTGGGCTC CATCTTTGTC TGGGCCTCGG GGAACGGGGG CCGGAACAT	900
60	GACAGCTGCA ACTGCGACGG CTACACCAAC AGTATCTACA CGCTGTCCAT CAGCAGCGCC	960
	ACGCAGTTTG GCAACGTGCC GTGGTACAGC GAGGCCTGCT CGTCCACACT GGCCACGACC	1020

TACAGCAGTG GCAACCAGAA TGAGAAGCAG ATCGTGACGA CTGACTTGCG GCAGAACTGC 1080
 ACGGAGTCTC ACACGGGCAC CTCAGCCTCT GCCCCCTTAG CAGCCGGCAT CATTGCTCTC 1140
 5 ACCCTGGAGG CCAATAAGAA CCTCACATGG CGGGACATGC AACACCTGGT GGTACAGACC 1200
 TCGAAGCCAG CCCACCTCAA TGCCAACGAC TGGGCCACCA ATGGTGTGGG CCGGAAAGTG 1260
 10 AGCCACTCAT ATGGCTACGG GCTTTTGGAC GCAGGCGCCA TGGTGGCCCT GGCCAGAAT 1320
 TGGACCACAG TGGCCCCCCA GCGGAAGTGC ATCATCGACA TCCTCACCBA GCCCAAAGAC 1380
 ATCGGGAAAC GGCTCGAGGT GCGGAAGACC GTGACCGCGT GCCTGGGCGA GCCCAACCAC 1440
 15 ATCACTCGGC TGGAGCACGC TCAGGCGCGG CTCACCTGT CCTATAATCG CCGTGGCGAC 1500
 CTGGCCATCC ACCTGGTCAG CCCCATGGGC ACCCGCTCCA CCCTGCTGGC AGCCAGGCCA 1560
 CATGACTACT CCGCAGATGG GTTTAATGAC TGGGCCTTCA TGACAACTCA TTCCTGGGAT 1620
 20 GAGGATCCCT CTGGCGAGTG GGTCCTAGAG ATTGAAAACA CCAGCGAAGC CAACAATAT 1680
 GGGACGCTGA CCAAGTTCAC CCTCGTACTC TATGGCACCG CCCCTGAGGG GCTGCCCCGA 1740
 25 CCTCCAGAAA GCAGTGGCTG CAAGACCCTC ACGTCCAGTC AGGCCTGTGT GGTGTGCGAG 1800
 GAAGGCTTCT CCCTGCACCA GAAGAGCTGT GTCCAGCACT GCCCTCCAGG CTTGCCCCC 1860
 CAAGTCCTCG ATACGCACTA TAGCACCGAG AATGACGTGG AGACCATCCG GGCCAGCGTC 1920
 30 TGCGCCCCCT GCCACGCCTC ATGTGCCACA TGCCAGGGGC CGGCCCTGAC AGACTGCCTC 1980
 AGCTGCCCCA GCCACGCCTC CTTGGACCCT GTGGAGCAGA CTTGCTCCCG GCAAAGCCAG 2040
 35 AGCAGCCGAG AGTCCCCGCC ACAGCAGCAG CCACCTCGGC TGCCCCCGGA GGTGGAGGCG 2100
 GGGCAACGGC TGCGGGCAGG GCTGCTGCCC TCACACCTGC CTGAGTGATG A 2151

(2) INFORMATION FOR SEQ ID NO:6:

40 (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 1591 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 45 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(vi) ORIGINAL SOURCE:
 50 (A) ORGANISM: Homo sapiens

(vii) IMMEDIATE SOURCE:
 (B) CLONE: sPSL.Fc

55 (xi) SEQUENCE DESCRIPTION: SEQ ID NO:6:

ATGCCTCTGC AACTCCTCCT GTTGCTGATC CTAAGGGGCC CTGGCAACAG CTTGCAGCTG 60
 60 TGGGACACCT GGGCAGATGA AGCCGAGAAA GCCTTGGGTC CCCTGCTTGC CCGGGACCGG 120
 AGACAGGCCA CCGAATATGA GTACCTAGAT TATGATTTC TCCAGAAAAC GGAGCCTCCA 180

	GAAATGCTGA GGAACAGCAC TGACACCACT CCTCTGACTG GGCCTGGAAC CCCTGAGTCT	240
	ACCACTGTGG AGCCTGCTGC AAGGCGTTCT ACTGGCCTGG ATGCAGGAGG GGCAGTCACA	300
5	GAGCTGACCA CGGAGCTGGC CAACATGGGG AACCTGTCCA CGGATTCAGC AGCTATGGAG	360
	ATACAGACCA CTCAACCAGC AGCCACGGAG GCACAGACCA CTCCACTGGC AGCCACAGAG	420
10	GCACAGACAA CTCGACTGAC GGCCACGGAG GCACAGACCA CTCCACTGGC AGCCACAGAG	480
	GCACAGACCA CTCCACCAGC AGCCACGGAA GCACAGACCA CTCAACCCAC AGGCCTGGAG	540
	GCACAGACCA CTGCACCAGC AGCCATGGAG GCACAGACCA CTGCACCAGC AGCCATGGAA	600
15	GCACAGACCA CTCCACCAGC AGCCATGGAG GCACAGACCA CTCAACCCAC AGCCATGGAG	660
	GCACAGACCA CTGCACCAGA AGCCACGGAG GCACAGACCA CTCAACCCAC AGCCACGGAG	720
20	GCACAGACCA CTCCACTGGC AGCCATGGAG GCCCTGTCCA CAGAACCCAG TGCCACAGAG	780
	GCCCTGTCCA TGGAACTTAC TACCAAAAGA GGTCTGTTCA TACCCTTTTC TGTGTCCTCT	840
	GTTACTCACA AGGGCATTCC CATGGCAGCC AGCAATTTGT CCGTCCTGCG GCCGCACTCT	900
25	AGAGACAAAA CTCACACATG CCCACCGTGC CCAGCACCTG AACTCCTGGG GGGACCGTCA	960
	GTCTTCCTCT TCCCCCAA AACCAGGAC ACCCTCATGA TCTCCCGGAC CCCTGAGGTC	1020
30	ACATGCGTGG TGGTGGACGT GAGCCACGAA GACCCTGAGG TCAAGTTCAA CTGGTACGTG	1080
	GACGGCGTGG AGGTGCATAA TGCCAAGACA AAGCCGCGGG AGGAGCAGTA CAACAGCACG	1140
	TACCGTGTGG TCAGCGTCCT CACCGTCCTG CACCAGGACT GGCTGAATGG CAAGGAGTAC	1200
35	AAGTGCAAGG TCTCCAACAA AGCCCTCCCA GTCCCCATCG AGAAAACCAT CTCCAAAGCC	1260
	AAAGGCCAGC CCCGAGAACC ACAGGTGTAC ACCCTGCCCC CATCCCGGGA GGAGATGACC	1320
40	AAGAACCAGG TCAGCCTGAC CTGCCTGGTC AAAGGCTTCT ATCCCAGCGA CATCGCCGTG	1380
	GAGTGGGAGA GCAATGGGCA GCCGGAGAAC AACTACAAGA CCACGCCTCC CGTGCTGGAC	1440
	TCCGACGGCT CCTTCTTCCT CTATAGCAAG CTCACCGTGG ACAAGAGCAG GTGGCAGCAG	1500
45	GGGAACGTCT TCTCATGCTC CGTGATGCAT GAGGCTCTGC ACAACCACTA CACGCAGAAG	1560
	AGCCTCTCCC TGTCCCCGGG TAAATAG	1591

5

CLAIMS

1. A composition comprising an isolated DNA sequence encoding a P-selectin ligand protein, said protein being characterized by the amino acid sequence set forth in SEQ ID NO:1 from amino acid 1 to amino acid 402.
2. A composition comprising an isolated DNA sequence encoding a soluble P-selectin ligand protein, said protein being characterized by the amino acid sequence set forth in SEQ ID NO:1 from amino acid 1 to amino acid 310.
3. A composition comprising an isolated DNA sequence encoding a mature P-selectin ligand protein, said protein being characterized by the amino acid sequence set forth in SEQ ID NO:1 from amino acid 42 to amino acid 402.
4. A composition comprising an isolated DNA sequence encoding a soluble mature P-selectin ligand protein, said protein being characterized by the amino acid sequence set forth in SEQ ID NO:1 from amino acid 42 to amino acid 310.
5. A composition comprising an isolated DNA sequence encoding a P-selectin ligand protein, said protein being characterized by the amino acid sequence set forth in SEQ ID NO:3.
6. An isolated DNA sequence capable of hybridizing under stringent conditions to the DNA sequence of any one of claims 1, 2, 3, 4 or 5.
7. The DNA sequence of any one of claims 1, 2, 3, 4, 5 or 6 operably linked to an expression control sequence.
8. A host cell transformed with the DNA of claim 7.
9. The host cell of claim 8, comprising a mammalian cell.

10. A process for producing a P-selectin ligand protein, which comprises:

- (a) culturing the host cell of claim 8 or claim 9 in a suitable culture medium; and
- 5 (b) purifying the P-selectin ligand protein from the culture medium.

11. A process for producing a soluble mature P-selectin ligand protein which comprises:

- 10 (a) co-transforming a host cell with the DNA sequence of claim 4, a DNA sequence encoding an (α 1,3/ α 1,4) fucosyltransferase, and a DNA sequence encoding a paired basic amino acid converting enzyme, each of said DNA sequences being operably linked to an expression control sequence;
- 15 (b) culturing the host cell in a suitable culture medium; and
- (c) purifying the soluble mature P-selectin ligand protein from the culture medium.

20 12. A composition comprising a P-selectin ligand protein characterized by the amino acid sequence set forth in SEQ ID NO:1 from amino acid 1 to amino acid 402, said protein being substantially free from other mammalian proteins.

25 13. A composition comprising a P-selectin ligand protein characterized by the amino acid sequence set forth in SEQ ID NO:1 from amino acid 42 to amino acid 310, said protein being substantially free from other mammalian proteins.

30 14. The composition of claim 13, further comprising a pharmaceutically acceptable carrier.

15. A composition comprising a protein characterized by the amino acid sequence set forth in SEQ ID NO:3.

35 16. A composition comprising an antibody which specifically reacts with the P-selectin ligand protein of claim 12.

17. A composition comprising an antibody which specifically reacts with the P-selectin ligand protein of claim 13.

18. A composition comprising an antibody which specifically reacts with the protein of claim 15.

19. A method of identifying an inhibitor of P-selectin-mediated intercellular adhesion which comprises

(a) combining a P-selectin protein with a P-selectin ligand protein characterized by an amino acid sequence selected from the group consisting of the amino acid sequence set forth in SEQ ID NO:1 from amino acid 1 to amino acid 402, the amino acid sequence set forth in SEQ ID NO:1 from amino acid 42 to amino acid 402, the amino acid sequence set forth in SEQ ID NO:1 from amino acid 42 to amino acid 310, and the amino acid sequence set forth in SEQ ID NO:3, said combination forming a first binding mixture;

(b) measuring the amount of binding between the P-selectin protein and the P-selectin ligand protein in the first binding mixture;

(c) combining a compound with the P-selectin protein and the P-selectin ligand protein to form a second binding mixture;

(d) measuring the amount of binding in the second binding mixture; and

(e) comparing the amount of binding in the first binding mixture with the amount of binding in the second binding mixture; wherein the compound is capable of inhibiting P-selectin-mediated intercellular adhesion when a decrease in the amount of binding of the second binding mixture occurs.

20. A method of treating an inflammatory disease which comprises administering a therapeutically effective amount of the composition of claim 14 to a mammal.

INTERNATIONAL SEARCH REPORT

Information on patent family members

national Application No

PCT/US 93/10168

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